Charles University in Prague

Faculty of Social Sciences

Institute of Economic Studies

Risk management of savings accounts

MASTER THESIS

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Declaration of Authorship

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Prague, 12. 5. 2013

Signature

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Abstract

This thesis deals with the risk management of savings accounts. Savings accounts are non-maturing liabilities bearing two embedded options. The first option is the client's right to withdraw deposits on notice. The second option is a bank's right to change the deposit rate on savings accounts whenever it wishes. This in practice means that a fierce competition may arise as banks can quickly react to competitor's change in the deposit rate. The embedded characteristics make the risk management of savings accounts challenging. We identify five key risks of savings accounts: liquidity risk, market risk (interest rate risk), systemic risk, reputational risk, and model risk. The thesis focuses on the interest rate risk and the method of replicating portfolios, which is a standard technique of the estimation of non-maturing liabilities' interest rate risk employed by banks. Using replicating portfolio approach, we derive that savings accounts are risky liabilities. We provide evidence that high deposit rates offered on numerous savings accounts in the Czech Republic have not been consistent with low market rates since January 2012, at least. We show that unsustainable deposit rates combined with competition among banks will lead to capital losses in some banks when market rates increase.

JEL Classification	C15, G21, G11, G32
Keywords	Non-maturing liabilities, interest rate risk, reinvestment, replicating portfolio, risk management, savings accounts, scenarios, simulations

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Abstrakt

Předložená práce se zabývá řízením rizik spořicích účtů. Spořicí účty patří mezi vklady na viděnou a jsou charakterizovány vysokou úrokovou sazbou a dvěma vtělenými opcemi. První opce dává klientovi právo vybrat si úspory na požádání. Podstatou druhé opce je právo banky změnit sazbu na spořicím účtu kdykoliv, což vede ke konkurenčnímu boji, ve kterém se banky předbíhají v nabízení nejvýhodnějších spořicích účtů. Díky těmto vtěleným opcím a relativně vysokým úrokovým sazbám na spořicích účtech je řízení rizik spořicích účtů složité. Tato práce popisuje pět hlavních rizik spořicích účtů - likviditní riziko, tržní riziko (úrokové riziko), systémové riziko, reputační riziko a modelové riziko. Práce se zejména soustředí na úrokové riziko a řízení tohoto rizika pomocí metody replikačních portfolií. Výsledkem analýzy úrokového rizika spořicích účtů je model, ze kterého vyplynulo, že tyto účty jsou rizikové produkty a sazby na nich jsou často mimo vývoj tržních sazeb. Ukazujeme, že příliš vysoké sazby kombinované s konkurenčním prostředím, které vzniklo v České Republice po vstupu několika malých bank soustředících se na spořicí účty, by mohlo vézt ke ztrátě kapitálu v těchto bankách v případě nárůstu tržních sazeb.

Klasifikace	C15, G21, G11, G32
Klíčová slova	Spořicí účty, řízení rizik, úrokové riziko, reinvestice, replikační portfolio, vklady na viděnou, simulace, scénáře

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Master Thesis Proposal

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Proposed Topic:

Risk management of savings accounts

Topic Characteristics:

Liquidity risk (or more precisely funding liquidity risk together with market liquidity risk) faced by a bank can be defined as the probability of the inability to meet obligations at reasonable costs in a timely manner, but such a definition does not entail all negative impacts that the bank and whole economy can face from the liquidity unease. Apart from the loss of funds that are withdrawn by panicking depositors during the run on the bank, there are more sources of potential losses arising from liquidity risk. Firstly, when banks do not trust one another and they are reluctant to trade among themselves and rather hold their funds, liquidity cannot flow into the system and whole economy cannot recuperate as banks do not fulfill their principal function, the intermediation of funds from those in the excess of them to those in the lack of them. Secondly, such hoarding of cash only leads to the loss of a potential reinvestment income gain that arises from repo operations and other reinvestment strategies. Thirdly, banks during the run on the bank must sell off their assets quickly and usually at loss to remain solvent, which further decreases their ability to fund themselves.

All the above mentioned factors are the result of bad liquidity risk management and they show the importance of prudent risk management. In 2007-2008 we saw sudden dry up on the interbank market that manifested us that liquidity can disappear quickly when banks are dependent on the short-term and easily available funding. We have also seen that without the confidence, the interbank market can remain illiquid for a very long time. The authorities aim to limit such occurrences in the future by introducing new regulation that aims to decrease liquidity risk. In 2010 The Basel Committee on Banking Supervision (BCBS) introduced the evolution of Basel II, Basel III, which reacts on apparent holes in the liquidity risk management within banks by introducing two ratios: Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR). LCR is expected to decrease short-term liquidity risk whereas NSFR focuses on the importance of long-term stable funding, thus decreasing long-term liquidity risk. Basel III, and particularly its liquidity part, is expected to enter into practice by 2018 and is nowadays under the observation period.

This thesis will focus on the development of the liquidity dry up during the subprime crisis and after it and it will also describe the liquidity part of Basel III. Nevertheless, the most importantly, the thesis aims to point out the potential source of liquidity and market risk in the Czech banking sector that may arise even under the liquidity regulation measures that are proposed by BCBS. This source of liquidity and market risk is increasingly popular product offered by banks in the Czech Republic: savings accounts. Savings accounts are becoming popular due to their characteristics, high interest rate offered to depositors and the possibility to withdraw deposits without long notice period.

Hypotheses:

1. Savings accounts are a potential source of liquidity risk in the Czech banking sector.
2. Savings accounts are a potential source of market risk in the Czech banking sector.
3. Liquidity on the market for savings accounts in the Czech Republic is expected to dry up easily due to a competitive increase in interest rates offered on savings accounts.
4. Competition in interest rates offered on savings accounts will lead to declining income that the bank earns from the reinvestment of deposits on savings accounts under the situation when central bank increases interest rates. This income will even turn negative under extreme case.

Methodology:

The methodology and the empirical part of the thesis will concentrate on the risk management of savings accounts, i.e. how the bank manages the risk arising from savings accounts including both sudden withdrawals on the clients' side as well as the risk arising from trading deposits on the interbank market.

The aim of the analysis is to support hypotheses that are introduced above. In the analysis we shall use the data that are provided by the Czech National Bank in the ARAD time series database. Nevertheless, the core data source of the analysis is the data provided by an anonymous bank located in the Central Europe. We shall employ simulations (Monte Carlo methods) to test our hypotheses.

Outline:

1. Introduction
2. Theoretical background
    - i. Characteristics of savings accounts
        - a) Risk management of savings accounts
        - b) Savings accounts liquidity risk
        - c) Savings accounts market risk
    - ii. Liquidity development during the crisis
    - iii. Liquidity and liquidity risk regulation under Basel III
    - iv. Market risk under Basel III
3. Empirical analysis
    - i. Empirical analysis of market risk and liquidity risk of savings accounts
        - a) The Czech banking sector
        - b) Savings accounts - their comparison across banks
        - c) Data description and introduction to the analysis
        - d) Empirical analysis
    - ii. Basel III impact on the analysis in the section 3i.
4. Conclusion

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Acronyms

10Y	Ten Years
1Y	One Year
2W repo rate	Two Week Repo Rate
3M	Three Months
5Y	Five Years
6M	Six Months
CAR	Capital Adequacy Ratio
CEE	Central and Eastern Europe
CEO	Chief Executive Officer
CNB	Czech National Bank
CZK	Czech Crown
MLE	Maximum Likelihood Estimation
NML	Non-Maturing Liabilities
O/N	Overnight
OLS	Ordinary Least Squares
OU	Ornstein-Uhlenbeck Process
PRIBID	Prague Inter Bank Bid Rate
PRIBOR	Prague Inter Bank Offered Rate
RWA	Risk Weighted Assets
SME	Small and Medium Enterprises
VAR	Vector Autoregression

1 Introduction

This thesis deals with the risk management of savings accounts. Savings accounts are non-maturing liabilities (demand deposits) and as such do not have fixed maturity. In this aspect are savings accounts similar to current accounts. However, savings accounts offer a substantially higher deposit rate than current accounts and therefore, banks' margin from savings accounts is lower than the margin from current accounts. Savings accounts bear two embedded options. The first option is the client's right to withdraw deposits on notice as the legal duration of savings accounts is one day. The second option is a bank's right to change a deposit rate whenever it wishes. Embedded options imply the uncertainty in the timing of cash flows, which makes the risk management of savings accounts challenging.

In this thesis we thoroughly describe the dynamics of savings accounts in the Czech Republic until 31 March 2013 and focus on the risk management of savings accounts. We identify five key risks of savings accounts: liquidity risk, market risk (interest rate risk), systemic risk, reputational risk, and model risk. The thesis focuses on the interest rate risk of savings accounts and describes the replicating portfolio approach, which is one of basic approaches used by many banks for the interest rate risk management of demand deposits.

The main contribution of this thesis is both theoretical and empirical analysis of savings accounts in the Czech Republic. We analyze the market and construct several replicating (reinvestment) portfolios. Our replicating portfolios differ from those presented in studies dedicated to modeling of non-maturing liabilities as we do not focus on the derivation of the optimal reinvestment using the optimization exercise. We rather define the reinvestment and derive potential net interest income from this reinvestment. We let banks in our analysis to create replicating portfolios from savings accounts according to the reinvestment used by many banks in the Czech Republic.

Using the replicating portfolio approach, we assess two hypotheses. In the first hypothesis we test whether savings accounts are a source of the interest rate risk for all banks in the Czech Republic and to what degree are different types of banks exposed to the interest rate risk of savings accounts. For this we define three types of banks and derive their interest rate risk management strategies from the behaviour on the market. The second hypothesis tests whether savings accounts will have a potential detrimental systemic impact.

The following text is structured as follows: Section 2 describes the dynamics of savings accounts in the Czech Republic. Section 3 focuses on the risk management of savings accounts and savings accounts' risks. Section 4 provides the theoretical assessment and the calibration of models employed in our analysis and section 5 is dedicated to the empirical analysis of the interest rate risk of savings accounts. Section 6 concludes.

2 Theoretical Background

In this chapter we first provide basic definitions and characteristics of deposit accounts and typical clients' characteristics of different deposit accounts, focusing mainly on savings accounts and clients of those accounts. Second, we address the dynamics of savings accounts in the Czech Republic.

2.1 Current Accounts and Term Deposits

Current accounts are deposits on demand, characterized by unlimited disposability (possibility to withdraw deposits on notice - sight deposits), low interest rates and high/moderate fees for account maintenance and services (Mejstřík, et al., 2009). Current accounts in retail (households and SME) represent one the most important parts of banks' liabilities and a stable source of funding for many banks in the Czech Republic. The core of current accounts reaches approx. 80% of the total account's balance in many banks.

Term deposits are deposits characterized by limited disposability within their maturity with early withdrawals being sanctioned by fees (Mejstřík, et al., 2009). In comparison with current accounts, term deposits usually offer a higher deposit rate (usually higher than inflation, depending on the longevity of the investment), but the client cannot withdraw (or can with a condition of paying a fee) the investment until defined maturity. Term deposits usually form an important part of banks' liabilities. Before the introduction of savings accounts, term deposits represented a traditional savings product used by many clients. Term deposits are, in terms of uncertainty, a safe liability, as clients cannot withdraw deposits on notice and a bank has enough time to prepare for expected maturity withdrawals.

CNB's statistics show that as of 31 March 2013 there were in retail CZK[1] 661 billion on current accounts and CZK 745 billion on term deposits (including building savings) in the Czech Republic. In total retail deposits there were CZK 1,795 billion. From this we derive that current accounts form 36.84% of all retail deposits in the Czech Republic and term deposits constitute 41.53% as of the

[1] Volumes in CZK, including foreign currencies exchanged to CZK.

same date. Remaining 21.63% are other demand deposits including savings accounts, passbooks and more.

2.2 Savings Accounts

We define savings accounts as a deposit on demand, characterized by unlimited disposability (client can withdraw (send to one or more transactional accounts) all balance on notice), high interest rates and low fees for maintenance and account operations. Savings accounts are non-maturing liabilities and as such do not have fixed maturity as term deposits. Recently, savings accounts have become one of the most popular deposit products (by banks as well as by clients) in the Czech Republic due to their unique characteristics; first, they combine the right to withdraw the money without a notice period (common feature of current accounts) with higher deposit rates (common feature of term deposits). Additionally, depositors can add new money whenever they want. Second, the savings accounts deposit rate can be changed at any time by a bank, which increases competitive pressures among banks as they can react quickly to competitor's changes in the deposit rate. In other words, banks may have a tendency to attract clients on high deposit rates. By doing so, such banks gain liquidity, but at the cost of a high deposit rate, which is a rather high cost of acquisition. All these characteristics are embedded in savings accounts, which in a certain sense transform savings accounts into options - into so called embedded options. All embedded characteristics imply uncertainty in the timing of future cash flows, making the risk management of savings accounts challenging.

2.3 Behavioural Patterns of Clients of Depository Products

Clients of depository products can select from three basic products: (i) current accounts, (ii) term deposits and (iii) savings accounts. In the context of clients' behavioural patterns, current accounts are pure transactional accounts. This means that the client uses the account mainly for transactional purposes, i.e. she maintains the balance of approximately two wages on a current account to cover her liquidity needs should these arise. The rest of client's available funds, i.e. savings, are redistributed to other instruments with a higher rate of return. These are usually term deposits, building savings and savings accounts.

Due to this predictable development, a bank can estimate the core of current accounts relatively easily. The dynamics of term deposits are also easily accessible as term deposits are instruments with known maturities. A client agrees to deposit a certain amount of money for a term given by the contract. A bank knows the timing of cash flows and can easily close the gap between assets and liabilities. Savings accounts, on the other hand, do not have either stable development as current accounts or defined maturity as term deposits. In other words, it is not possible to estimate the development of volumes on savings accounts in the same way as with current accounts and term deposits.

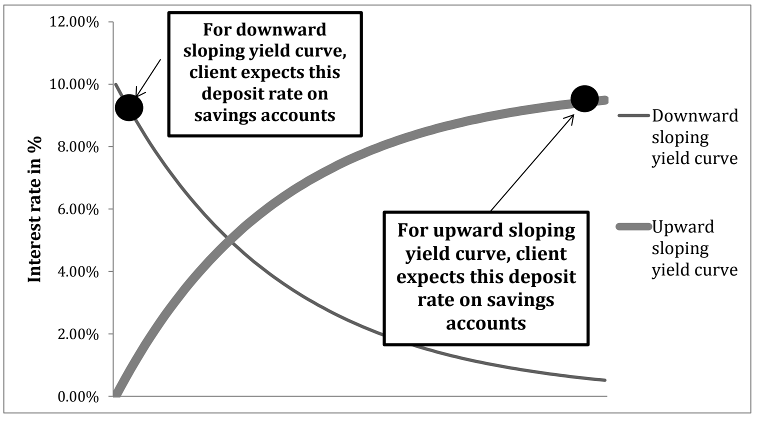
We distinguish two important behavioural classes of deposit accounts' clients - active and passive clients. Passive clients are interest rate insensitive, i.e. they do not follow changes in deposit rates and keep their money in a bank to which they are loyal to. That happens either because passive clients are not aware of higher returns that are provided by other banks' products (e.g. old people without the ability to use the internet), because they do not trust other banks, or because they just do not care about this issue. Passive clients either attain all their funds at current accounts or select one savings account at which they hold their funds no matter the deposit rate development in their bank or in other banks. Passive clients also invest in term deposits as they have no tendency to withdraw balances during the term. Passive clients' deposits can be considered as a safe liability with relatively known risk by banks. Active clients, sometimes called as "bank tourists", on the other hand, are extremely interest rate sensitive and thus flexible when transferring their money between banks and different depository products when unsatisfied with the deposit rate currently on offer in their bank. Active clients select savings accounts as these are attractive instruments due to a high deposit rate and a possibility to withdraw balances on notice. Active clients that save on savings accounts are sensitive to changes in deposit rates offered on savings accounts and they obviously require the highest rate. If not provided with this rate, they turn to competition. We find that active clients' expectations in the case of the savings accounts' deposit rate can be described by the shape of the yield curve, see Definition 1 for the description of the yield curve.

Definition 1: Yield curve

We define the yield curve as the term structure of interest rates or the zero-coupon curve at time t, which corresponds to the definition by Brigo and Mercurio (2001) who define a yield curve as a plot of simply-compounded maturities T up to one year and annually compounded rates for maturities T higher than one year.

Figure 2.1 shows that for an upward sloping yield curve (long-term instruments having higher yields than short-term ones), the client expects the deposit rate equal to long-term maturities and the opposite applies to the downward sloping yield curve (short maturities having higher yields than long ones). Evidently, the client always expects the best rate regardless of market rates. The function of clients' expectations is thus well described by the function E(client) = Max(short-term rate, long-term rate).

Figure 2.1: Clients' expectations about the deposit rate on savings accounts under different yield curves



Source: Author

We observe that the active type of clients might be attractive for new banks as it is relatively easy to attract liquidity through savings accounts. However, it remains a challenge to retain these active clients in the long term owing to the fact that to attain them, a bank always has to offer the best rate on the market. Due to this, banks are sensitive to changes in market rates as clients always expect an increase in savings accounts' deposit rates when market rates increase, and stable or slowly decreasing deposit rates when market rates decrease. Evidently, savings accounts bring high interest rate sensitivity to the market as both clients and banks are highly interest rate sensitive.

There is evidence that a large portion of savings accounts' clients in the Czech Republic are active clients. On 21 February 2013, Tůma (2013) published an article dedicated to dynamics of savings accounts in the Czech Republic. This article included a survey about clients of savings accounts. Respondents could choose from four answers to the question of whether they have a savings account: (i) several, (ii) I am a "bank tourist" who changes savings accounts often, (iii) one savings account for many years, or (iv) none savings account. By 5 March 2013, there we 330 answers with following results: (i) 45.15%, (ii) 17.88%, (iii) 26.36%, and (iv) 10.61%. From this survey, we can conclude that the majority of respondents have a savings account and that many are "bank-tourists".

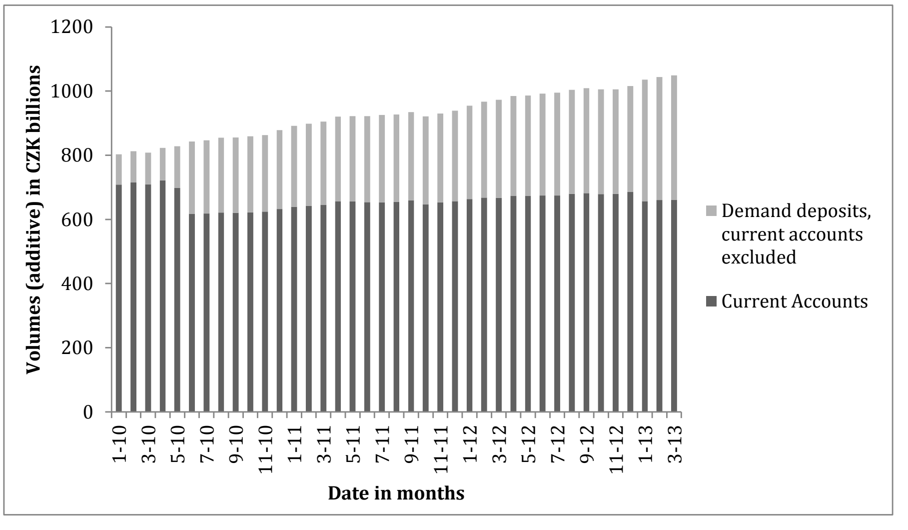
2.4 Dynamics of Savings Accounts in the Czech Republic

As of 31 March 2013, there are around fifteen savings accounts offered by banks in the Czech Republic. The oldest one is ING Konto (used to be known as Orange account) introduced on 1 November 2001. In 2007, more banks (ERA - ČSOB, LBBW) started to offer savings accounts and in recent years, some banks started to focus on savings accounts as a source of revenues. This resulted in increasing importance of savings accounts in banks' liabilities. It also resulted in the competitive environment where some banks attract clients, active clients, by zero fee policy and high savings accounts' deposit rates.

2.4.1 Deposits

The importance of savings accounts has been increasing in the Czech Republic in the past years. Although there are no official statistics of total CZK deposited on savings accounts in the Czech Republic, as these are not reported separately by the Czech National Bank, we can approximate them. Savings accounts are included in Savings demand deposits and reported together with other demand deposits in the category Demand deposits. Demand deposits in retail (households) reached CZK 1,049 billion as of 31 March 2013, from which current accounts amounted to CZK 661 billion and remaining categories to CZK 388 billion. Figure 2.2 shows a decrease in current accounts resulting from the transfer of savings accounts from current accounts to Savings demand deposits as of 30 June 2010. Since then, the volume of Demand deposits, current accounts excluded, has been growing steadily. This increase might be attributed to increasing demand for savings accounts. We estimate aggregate savings accounts to be worth approximately CZK 250 billion up to CZK 300 billion as of 31 March. This approximation rises from the market knowledge (increasing volumes in demand deposits in banks that offer attractive savings accounts). We expect further increases in aggregate savings accounts due to their ongoing attractiveness.

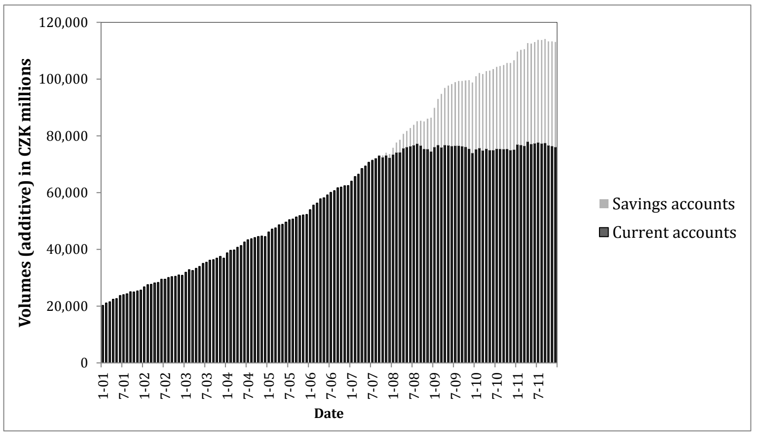
Figure 2.2: The growth of volumes on aggregate current accounts and savings accounts (savings accounts included in Demand deposits, current accounts excluded) from 31 January 2010 to 31 March 2013



Source: Author based on the data from ARAD time series database provided by the CNB. The transfer of savings accounts deposits from current accounts to Savings demand deposits (a category belonging to Demand deposits) on 30 June 2010 resulted in the decrease on aggregate current accounts by CZK 86 billion. In other words, by 30 June 2010, there was at least CZK 86 billion on savings accounts in the Czech Republic, which increased the category Demand deposits without current accounts by 38.2%.

To further demonstrate the increasing importance of deposits on savings accounts, we include Figure 2.3 which compares deposits on current accounts to those on savings accounts in an anonymous bank located in the Czech Republic ("the Bank"). As we can see, since the introduction of savings account in the Bank, the deposits on savings accounts sharply increased. By 31 December 2011, clients deposited CZK 37.2 billion on savings accounts whereas in 30 July 2007, there was CZK 27 million. We also see that the growth of deposits on current accounts got somewhat moderate since the introduction of savings account in the Bank. This stems from the outflow of deposits from current accounts to savings accounts. Savings accounts now form roughly one half of deposits on current accounts and due to the evident constant growth of current accounts since 2008; we expect further growth of savings accounts' deposits in the Bank.

Figure 2.3: Current accounts compared to saving accounts in the Bank in 2001 - 2011



Source: The Bank

As far as increases in savings accounts' volumes in other banks are considered, we find important evidence from annual and quarterly reports[2] of two small banks: Air Bank and Equa bank. We cannot assess more small and medium-sized banks that offer high deposit rates (Zuno, mBank) as their numbers are reported together with their parent companies. This applies for ING as well. Another problem is that banks do not report savings volumes separately, but include them into demand deposits. In many large banks (ČSOB, KB, Česká spořitelna and others), current accounts represent majority of demand deposits. Therefore, we have no means how to derive the development of savings accounts in large banks.

Air Bank offers only two deposit products - a savings account and a current account. In Air Bank's 2011 annual report we find that clients' deposits by 31

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[2] All tables with simplified reports are included in Appendix 8.2 and the full version of annual and quarterly reports may be found on webpages of respective banks.

December 2011 totaled CZK 2,234 million; thereof CZK 27 million was money placed on current accounts. It means that majority (CZK 2,207 million) of Air Bank's liabilities available on notice were deposits in savings accounts. By 30 June 2011 clients' deposits (current and savings accounts included) increased from CZK 2,233 million to CZK 18,897million. By 31 September 2012 deposits in Air Bank further increased to CZK 25,052 million and by 31 December 2012, CZK 30,696 billion. From this CZK 30,696 billion only CZK 458 million is on current accounts. These numbers directly imply that savings accounts amount to CZK 30,238 billion in Air Bank as of 31 December 2012 and represent 98.51% of all retail liabilities. Given this analysis, Air Bank is a bank that reports significant increases in liabilities and that is extremely dependent on savings accounts. Equa bank reports impressive increases on demand deposits as well, even though to lesser extent than Air Bank. From 31 December 2011 to 31 September 2012 deposits available on notice increased from 4,482 CZK million to CZK 5,688 million and in December 2012, Equa Bank reports CZK 7,492 billion of deposits available on notice.

We might conclude that the importance of savings accounts in banks' liabilities increases as we observe significant inflows into demand deposits in analyzed banks. We argue that there is a similar trend in other banks that offer high or moderate deposit rate bearing savings accounts. We also observe an unmistakable trend of increases in aggregate savings accounts, which indicates that savings accounts are becoming a popular product.

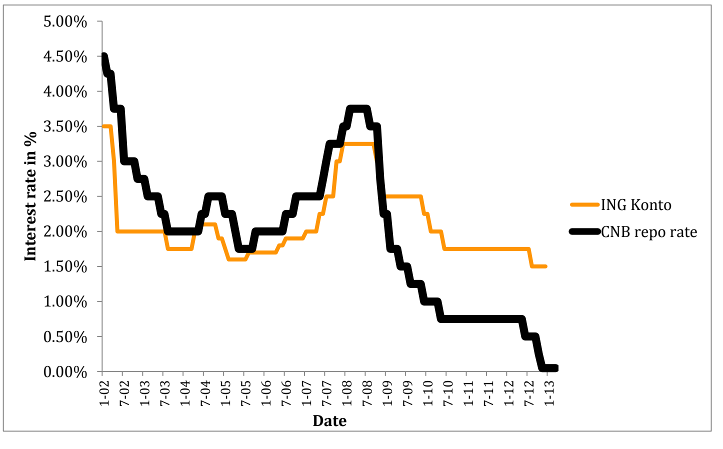
2.4.2 Deposit Rates

The following text describes important savings accounts' deposit rates and their adjustment during recent years. We focus closely on three rates: ING Konto's, mBank's and Air Bank's deposit rate. We select ING Konto due to its historical importance and Air Bank due to its prevailing high deposit rate. Figure 2.4 shows the development of the deposit rate on ING Konto compared to the CNB 2W repo rate.[3] We see that the deposit rate on ING Konto was under the 2W repo rate until September 2008. We focus in more detail on the adjustment of the ING Konto's deposit rate to market rates (represented by the 2W repo rate). We find that the adjustment of ING Konto's deposit rate differs significantly

[3] A rate under which CNB accepts surplus liquidity from banks and in return provides collateral of securities. The usual duration of repo tender is 14 days.

when we compare the adjustment until 2007 (recall that until 2007 ING is the sole provider of savings accounts in the Czech Republic) and after 2007. Until 2007, ING Bank adjusts the deposit rate when the average difference between the deposit rate and the 2W repo rate is 40 basis points. After 2007, ING Bank adjusts the rate only when the difference between the deposit rate and the 2W repo rate increases significantly (is more than 100 basis points on average). There are several possible reasons for this: first, in 2007, the crisis started in the European Union. Second, more savings accounts entered the market in 2007 and ING ceased to be the sole provider. Third, ING Bank received state support in the Netherlands and management strategies of the bank changed. The exact reason why ING changed the policy of adjustment is not straightforward and will likely be a combination of these factors. As of 31 March 2013, the ING deposit rate equals 1.5% and is not expected to increase until significant increases in the 2W repo rate occur as in October 2012, ING announced a decrease from 1.75% to 1.5% due to the prevailing low 2W repo rate.[4]

Figure 2.4: ING's interest rate during 1 January 2002 - 31 March 2013



Source: Author based on ING Bank

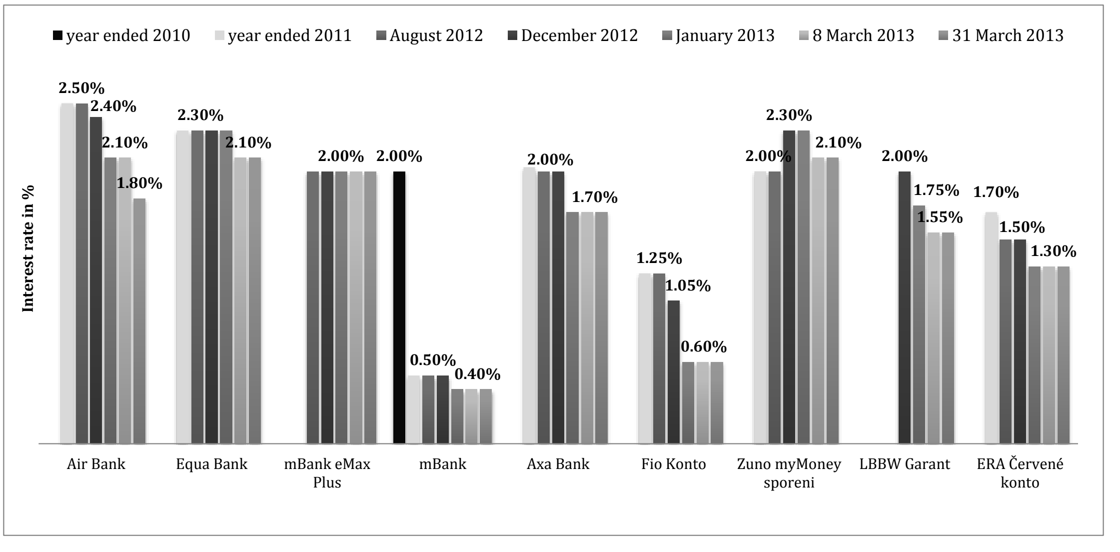
During 2010 - 2011, many new banks offering savings accounts entered the market. These new banks focus on savings accounts and due to this we have been observing marketing campaigns that aim to attract depositors by offering

[4] Even though this thesis provides the analysis of savings accounts until 31 March 2013, we note that ING decreased the rate to 1.2% during April 2013, which supports our assumption of no further increases until significant increase in market rates.

higher deposit rates than is the average deposit rate. Figure 2.5 shows deposit rates offered on several (not all) savings accounts in selected banks in the Czech Republic as of seven dates: year ended 2010, 31 December 2011, 31 August 2012, 31 November 2012, 26 January 2013, 8 March 2013 and 31 March 2013. To further illustrate the interest rate sensitivity of clients, we will firstly focus on the development of the deposit rate in mBank as a case study. Figure 2.5 demonstrates that at the beginning of 2010 the deposit rate on eMax (savings account in mBank) amounted 2%. During 2011, mBank sharply decreased eMax's deposit rate to 0.05%. This sharp decrease was followed by setting up second savings accounts eMax Plus with the base deposit rate equal to 0.5% as well, but with an extra deposit rate equal to 2%. mBank was apparently losing clients with a rate of 0.5% and decided to return to a higher deposit rate to attain and even attract new ones. However, the deposit rate equal to 2% is only for balances up to CZK 100,000 and the client has to use the account actively. Still, it demonstrates the interest rate sensitivity of clients as otherwise mBank would have no incentives to set up another savings account with a higher deposit rate. We also highlight the development of the deposit rate in Air Bank. As of 19 March 2013, Air Bank announced a decrease in the deposit rate from 2.1% to 1.8%. This was the third decrease in four months as in January 2013, Air Bank decreased the rate from 2.4% to 2.1% and in October 2012 it decreased the rate from 2.5% to 2.4%. These are obvious steps for two reasons. First, due to prevailing low market rates, Air Bank is still offering one of the three highest deposit rates on the market with the rate of 1.8% (considering only banks, not other institutions) as it promised in its extensive marketing campaign. Second, Air Bank has already attracted a lot of depositors and paying them high 2.4% and 2.1% interests was getting unsustainable during low market rates.

Figure 2.5 also displays that in January 2013 a majority of deposit rates on savings accounts amounted to between 1.5% and 2%, what makes them comparable to the 10Y Czech government bonds average monthly yield during January 2013 of 1.41%. Since 1 January 2013, we observe a general trend of decreasing deposit rates due to historically minimal market rates and, for example, Tůma (2013) and Bubák (2013a) argue that further decreases are expected. However, decreased deposit rates still remain high when compared to the central bank's 2W repo rate of 0.05%, and low money market as well as government bond yields. These high savings accounts' deposit rates result from (i) interest rate sensitivity of clients and banks, (ii) banks' marketing strategies and (iii) increasing attractiveness of savings accounts as a source of funding. When market rates start to increase, it is probable that many banks will start to compete for depositors by increasing deposit rates. Otherwise, banks might face withdrawals as there will always be one bank that will offer better rate and active clients will move their funds to this bank. As savings accounts are not subject to any special regulation in the Czech Republic,[5] competitive pressures among banks can develop beyond sustainable levels, resulting in the unsound risk management of savings accounts, as we shall provide evidence later.

Figure 2.5: Highest deposit rates offered on savings account in selected banks in the Czech Republic as of year ended 2010, December 2011, August 2012, November 2012, January 2013, 8 March 2013 and 31 March 2013



Source: Author based on www.produktovelisty.cz and individual banks. Some banks provide seasonal offerings of higher deposit rate (Axa Bank with savings account JINAK with 2.9% and their Winter offer with 2.5% or ING Bank with 2.5% for new clients up to 5 months during December 2012). Nevertheless, in Figure 2.5 we provide long-term development of deposit rates that are not offered seasonally. Seasonal offerings are merely targeted to attract liquidity in the

[5] We find no evidence for the regulation of savings accounts with two exceptions, Belgium and France. In Belgium there is a cap on the deposit rate (the deposit rate is derived from the ECB base rate + loyalty premium that is limited), special tax treatment of savings deposits and Maes and Timmermans (2005) also mention notice periods on withdrawals that exceed certain amount. In France, some savings accounts are a subject to regulation of deposit rates and there are limits on balances that can be deposited on the accounts.

short-term and cannot be considered as the representative savings accounts' deposit rate. Axa Bank deposit rate is for balances up to CZK 5 million, otherwise 1.3%. LBBW rate 1.75% is for balances over CZK 100,000. Era červené konto 1.5% rate is for balances over CZK 50,000. Some banks may link their savings account to other products - for example to have savings account is contingent on having current account. Still, these features tend to diminish due to competitive pressures - client rather goes to the bank that does not oblige her to such connections among products. Further restrictions as interest zones (Air Bank introduced interest zones during March 2013 and many other banks impose restrictions of high deposit rate for balances that exceed certain amount) may apply.

3 Risk Management of Savings Accounts

This chapter first provides a list and description of savings accounts risks. Second, it focuses on the theoretical description of the risk management of savings accounts. We stress that the detailed literature review behind the theory, mainly of different models used in our analysis, is described in section 4. This chapter mainly serves as an introduction to the topic and description of the relevance of sound risk management of savings accounts.

3.1 Risks of Savings Accounts

Banks are exposed to several risks arising from savings accounts. Sources of these risks are embedded characteristics of savings accounts, competition as well as risks that arise from the characteristics of the banking business itself. We identify five key savings accounts risks: liquidity risk, market risk, systemic risk, reputational risk, and model risk. These risks are not exclusive and are highly interconnected.

Liquidity risk: Liquidity risk can be defined as the probability of a situation when a bank cannot meet its obligations as they become due (Mejstřík, et al., 2009). Alternatively, liquidity risk represents a situation when a bank is not able to finance itself without excessive costs. Liquidity risk stems from different timing of bank's cash inflows and cash outflows. Savings accounts are non-maturing liabilities. Their liquidity risk is represented primarily by unexpected withdrawals of client's deposits (embedded option of the client). This situation occurs in two cases: (i) some depositors withdraw funds and transfer them to a higher yield bearing product or a savings account, or (ii) bad bank's prediction on customers' behaviour and preference. A bank is therefore exposed to severe liquidity risk as it needs funds to honour leaving depositors in a timely manner. However, these funds are obviously invested in instruments with longer maturities, which creates a funding gap for a bank. A bank has several options to remain liquid: it can either sell a part of its assets or enter a repo operation. However, a fire sale of a part of the portfolio might affect the bank's profitability. This situation amplifies under increasing market rates - the value of bonds decreases and a bank sells these assets at a loss, which creates connections between liquidity and market (interest rate) risk. In the case of savings accounts, withdrawals are quite probable under increasing market rates as active clients "search for yield" and move their deposits to a bank that offers a higher rate.

Market risk: Market risk is the risk of changes in the value of an instrument or a portfolio of instruments. These changes in values are a result of unexpected changes in market conditions, such as changes in interest rates or stock prices. Resti and Sironi (2007) present five market risk categories: exchange rate risk, interest rate risk, equity risk, commodity risk, and volatility risk. In the case of savings accounts, the interest rate risk is of importance. First, the savings accounts' interest rate risk can result in portfolio losses for a bank in the period of increasing rates. Under the situation of sudden withdrawals, a bank, to remain solvent, needs to sell off its bond portfolio at a loss due to the new higher rates. Second, interest rate changes as well as changes in competitors' rates lead to changes in the deposit rate (i.e. embedded option of the bank). Increasing market rates push a bank to increase the deposit rate, which decreases the margin from its portfolio. In the context of our analysis, we mainly focus on the second implication of the interest rate risk and show that competition leads to negative net interest income from savings accounts under the assumption that a bank actively participates in the competition and increases the deposit rate beyond sustainable levels.

Reputational risk: BCBS (2009) defines reputational risk as "the risk arising from negative perception on the part of customers, counterparties, shareholders, investors, debt-holders, market analysts, other relevant parties, or regulators that can adversely affect a bank's ability to maintain existing, or establish new, business relationships and continued access to sources of funding." This definition reflects the fact that banking is based on confidence. Because of the embedded option, banks can easily manipulate the deposit rate on savings accounts. Some banks attract new clients for seasonal offerings during which they promise a high teaser rate to a client compared to its competitors for a certain period. After this period, a bank can lower the rate to a market level. This is a common tactic of some banks in the Czech Republic, even though it tends to diminish as clients get aware of this (Tůma, 2013). Other banks can commit to hold the deposit rate among the highest rates in the market. A typical example of this strategy is, for example, Air

Bank and LBBW. Air Bank promised to maintain its deposit rate among the 3 highest rates on the market, which in practice translates into the third best. LBBW promised not to decrease the deposit rate during 12 months after setting up the account. These all are important commitments as banks in the competitive environment are not sole providers of the product and are thus exposed to reputational risk. The failure to keep such commitment might cause unsatisfied clients to be attracted by competitors, which can be done relatively easily since there are neither strict rules nor high costs to open a new savings account in a different bank due to common zero fee policy of savings accounts in many banks.

Systemic risk: Systemic risk can be defined as a risk that influences the whole industry through market contagion. Evidently, both systemic and reputational risks of savings accounts are highly connected. Systemic risk of savings accounts in the banking sector increases as the proportion of savings accounts in banks' liabilities increases. Savings accounts raised important financial stability issues in Belgium as their proportion formed approximately 30% of total banks' funding by 2005 (Maes and Timmermans, 2005). There are three systemic risk concerns of savings accounts in the Czech Republic. First, the current lower share of savings accounts in the Czech banking sector's liabilities does not imply their significance yet (approx. 7.7% - 9.3%), but they have been becoming extremely popular among clients and banks. We identified that volumes of savings accounts increased significantly in recent years and continue to grow, which implies that systemic risk of savings accounts will increase. Second, in addition to this popularity, possible cash inflow to savings accounts might be expected from buildings savings due to decreasing state support of this product (Horváth and Teplý, 2013). Banks will compete to attract these new deposits by a high deposit rate, what will further squeeze their margins and thus profitability. Third, corporate governance of Czech-based banks highly dependent on savings accounts plays an important role. A majority of new and the most active banks depending on savings accounts is usually owned by large foreign owners. As the Czech banking sector reports capital and liquidity surplus, the parent companies lacking liquidity may have a tendency to, by offering high deposit rates, remove liquidity from the Czech Republic to stand their problems in home or international markets. Consequently, the problem of foreign banks might be indirectly transmitted to the Czech banking sector.

Model risk: Model risk is a risk of banks using an incorrect model in the risk management of savings accounts (Maes and Timmermans, 2005). A bank needs to correctly define several models and it has only historical data to do so, which may not be enough as future is always uncertain. Bodemer (2011) points out that the risk management of savings accounts relies on the assumption that a bank has all these models correctly defined. However, misspecifications of the model can arise, which result in estimations that may not be in accordance with the behaviour of clients or the market.

Last but not least, we argue that all risks have been increasing substantially due to the accelerating pace of technology in banking. For example, the internet and mobile banking enable clients to easily transfer their money. Fast money transfers should be considered by a bank as liquidity pressures may arise quickly and a bank must be prepared to stand them.

3.2 Risk Management of Savings Accounts - Theoretical Models

Savings accounts are risky liabilities with a highly interest rate sensitive and unstable margin. Due to their embedded options, savings accounts cannot be hedged by standard risk mitigation techniques used for other bank's liabilities, such as current accounts or term deposits. As non-maturing liabilities (demand deposits), savings accounts have zero contractual maturity, similar to current accounts. However, as opposed to current accounts, the savings accounts' deposit rate is many times higher than the current accounts' deposit rate. This implies lower bank's margin from savings accounts than from current accounts. Banks usually reinvest demand deposits (both current as well as savings accounts) into government bonds, short and medium-term rates such as PRIBOR, long-term swap rates, and consumer and corporate loans. When a bank receives 3% from the reinvestment and it pays 0.01% to the client of the current account, it still, after the deduction of other costs such as operational costs and obligatory insurance, remains with a substantial margin of 2.99% from the reinvestment. However, with the savings account's deposit rate equal to 2%, the margin is evidently lower and small changes in the interest income from the reinvestment, stemming from changing market or deposit rates, are immediately and substantially reflected in the magnitude of the margin from savings accounts. Due to this, the margin from savings accounts reinvestment is more interest rate sensitive than the margin from current accounts.

The interest rate sensitivity of savings accounts is closely connected to the approximation of the effective maturity (or duration) of savings accounts. The approximation of duration of savings accounts is an important issue in the risk management of savings accounts and demand deposits as well. Even though the contractual maturity of savings accounts is zero (the legal duration of demand deposits is overnight), the reinvestment or effective maturity of savings accounts is higher as a majority of depositors leaves their balances in a bank (Maes and Timmermans, 2005). A rational bank therefore redistributes the core of savings accounts into medium-term and a long-term investment bearing a higher rate of return and provides a positive maturity transformation. However, a bank needs to estimate the effective maturity of savings accounts properly to ensure that it possess available funds to simultaneously cover unexpected withdrawals and to attain a stable margin from savings accounts. Ideally, the margin from savings accounts should compensate a bank for a higher deposit rate, transactional costs and also for all risks that arise from savings accounts. A bank incorrectly assuming that savings accounts have short maturity will invest those into short-term assets that cannot provide such high returns as long-term ones. Should market rates be low, such bank may even receive lower income from the reinvestment than is the deposit rate paid to the client. On the other hand, overestimation of the maturity may lead to an inability to cover withdrawals in the short-term as a bank would need some time to sell its assets to raise enough funds to cover unexpected withdrawals.

The aim of the risk management of demand deposits is to ensure stable margin from demand deposits. This is possible in the case of current accounts, but savings accounts are another story. In a competitive environment, there are constant pressures to hold or to increase the savings accounts' deposit rate. A bank either increases the deposit rate when competitors do, or it does not increase the rate and risks that clients will withdraw their deposits as in the case of mBank in section 2.4.2. Additionally, not all clients are "active ones", but the increased deposit rate is applied to all clients of the particular product. A bank must estimate the share of "active" clients among all clients to ensure that it does not increase the rate needlessly. Margins from savings accounts are unstable as a bank reinvests balances on savings accounts into some long-term and medium-term instruments with fixed yield under some deposit rate, but as deposit rates, due to competition or changes in the clients' behaviour, adjust often, the margin can quickly change.

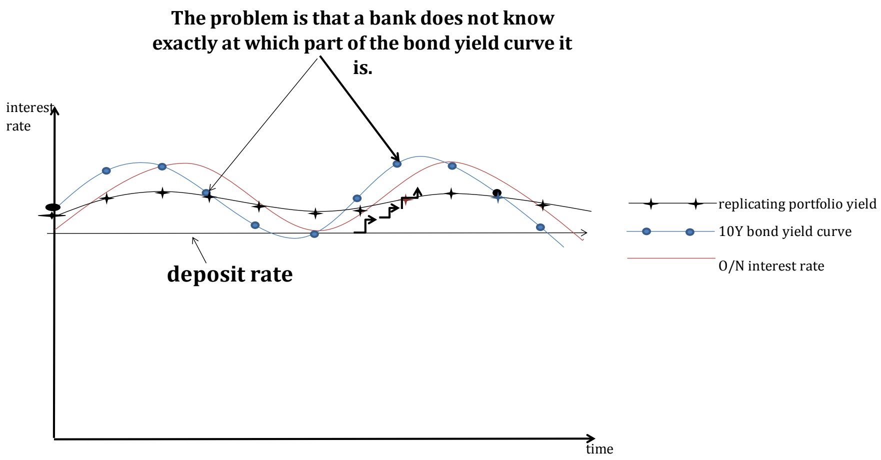
3.2.1 Replicating Portfolio Models

To ensure stable margin and to estimate the effective maturity of demand deposits, banks in Europe usually employ replicating portfolio models and simulations. A Replicating portfolio is a portfolio that replicates dynamics of demand deposits. There are two classes of replicating portfolio models. First, static replicating portfolio models are based on once-in-a-time calculation of amounts/weights of savings deposits reinvested into pure-discount instruments with different maturities (Maes and Timmermans, 2005; Kalkbrener and Willing, 2004). These weights are estimated by optimization that focuses either on the maximization of the margin or the minimization of the variance of the margin. The maturity of savings accounts is then defined as the duration of the replicating portfolio. Second, there are dynamic replicating portfolio models (Frauendorfer and Schurle, 2006; Dewachter, et al., 2006). Dynamic replication includes changes in weights. Weights changes are based on the joint development of simulated market rates, deposit rates and balances on savings accounts. Frauendorfer and Schurle (2006) claim that the dynamic replicating portfolio approach leads to more optimal division into different maturity tranches in such a way that the margin can be substantially larger under the dynamic approach than under the static approach.

The construction of both classes of the replicating portfolio models requires the knowledge of the historical development of market rates that are used to generate the yield curve, deposit rates and volumes. These processes must be estimated correctly; otherwise a bank is exposed to model risk. Jointly, these models define available funds that can be reinvested and a bank, according to the optimization exercise, finds optimal reinvestment. The margin from the portfolio is than calculated as the interest income from the reinvestment minus the deposit rate expense paid to the client (which usually takes a form of the recapitalization of volumes as majority of depositors attains their funds in a bank). In theory, the replicating portfolio of demand deposits should assure stable yields no matter what market rates are. To attain such stable yield, a bank needs time to build the portfolio up. During this time, a bank is exposed to changes in interest rates.

However, we find that even the buildup replicating portfolio of savings accounts does not assure a stable margin. Figure 3.1 demonstrates the margin from the replicating portfolio of savings accounts' core balance. We see that the deposit rate is near to the yield a bank gains from the replicating portfolio. The deposit rate close to the yield from the replicating portfolio indicates that margins from savings accounts are low, as discussed above. During a low-market rate environment (a decreasing part of the yield curve), banks may face severe liquidity risk from savings accounts because of unexpected withdrawals. However, due to low pressures to increase deposit rates when market rates are low, banks do not face the risk that the deposit rate offered on savings accounts will overlap the yield curve. On the other hand, as soon as market rates start to increase, there will be pressures to increase savings accounts' deposit rate not just from the increasing inter-bank competition, but also from other market players as other products (bonds, assets, funds, etc.) will start to provide a higher yield than savings accounts. Increasing deposit rate in an actively bidding bank would sooner or later exceed the yield curve that remains with an approximately constant margin pursued by the replicating portfolio. Therefore, increasing market rates will result in three consequences: (i) decreasing margin from savings accounts, (ii) unstable margin, or even (iii) negative margins under the assumption that a bank does not stop increasing the deposit rate and lets other banks to compete. Adding other costs, such as obligatory insurance, the net loss might be substantial and have a visible impact on bank's capital. We focus on this issue in the following empirical analysis, where we provide stress tests of the cumulative net interest income from the reinvestment of savings accounts for rapidly increasing market rates. We also find that banks that enter the market during low market rates do not have an opportunity to build up a high yield replicating portfolio. In theory, such banks should provide low deposit rate bearing savings accounts. In practice, the situation differs.

Figure 3.1: Graphical expression of the net interest income from savings accounts



Source: Author

3.2.2 Flaws of the Replication Approach and other Models

It has been argued that static replicating portfolios provide ambiguous results and are prone to the model risk. Under different stress tests, the duration estimate (the effective maturity) is found to differ substantially (Maes and Timmermans, 2005). To account for this limitation, Maes and Timmermans (2005) propose to rely on several models at once, not only on the static replication.[6] Another possibility is to employ the dynamic approach. Dynamic replicating portfolios, apart from the historical estimation, include simulations. This enables to obtain an average margin for several scenarios of the market rate as each market rate scenario results in different deposit rates and volumes, which subsequently means different reinvestment, i.e. deposits are always reinvested at different weights - dynamically. This ensures more optimal reinvestment than the static replication where deposits are redistributed based on the once-in-time calculation of weights. Dynamic replicating portfolios are extensively described, for example, in Frauendorfer and Schurle (2006). Another flaw is that all either static or dynamic replicating portfolios in Frauendorfer and Schurle (2006), Maes and Timmermans (2005), Kalkbrener and Willing (2004)

[6] The supervision of savings accounts is problematic due to differences in estimated duration under different stress tests as well as among different banks. Maes and Timmermans (2005) state that the usage of more models at once may enable the regulator to better assess average duration of the sector.

and Dewachter, et al. (2006) assume reinvestment only into zero-coupon instruments with known maturities. However, the assumption that a bank reinvests only in money and bonds[7] is a simplification necessary for the optimization exercise that is not possible to reflect that there are higher yield reinvestments available. In reality, a bank reinvests a large part of funds into loans and mortgages. This means that the margin from the replication is the revenue only from a part of deposits. Apart from the class of replicating portfolio models, there are models that aim to assess the present value of savings accounts, which enables a bank to better assess the value of the provision of savings accounts. These are the net present value Monte Carlo simulation approach, the Option Adjusted Spread mentioned by Maes and Timmermans (2005), and the valuation model developed by O'Brien (2000). Last but not least, Dewachter, et al. (2006) estimate simultaneously the dynamic replicating portfolio model and the no-arbitrage multi-factor flexible-affine term structure model. Authors argue that the no-arbitrage multi-factor flexible-affine term structure model is able to estimate the value of non-maturing liabilities, which is its main advantage when compared to dynamic as well as static replication. Still, even though having some disadvantages, static and dynamic replication remains a sound method that is used for the risk management of non-maturing liabilities by many European banks.

3.2.3 Differences between the Risk Management of Savings Accounts, Term Deposits and Current Accounts

Even though we focus in detail on savings accounts, we consider it relevant to describe the risk management of other deposit accounts, namely term deposits and current accounts. Our aim is to highlight important differences between the risk management of current account, term deposits and savings accounts to show that savings accounts are substantially riskier instruments than other demand deposits and term deposits. Table 3.1 summarizes important differences between all three types of depository products.

[7] 1/3 of the reinvestment on the money and bond market usually comprises of long maturities (10Y and 15Y government bonds and currency swaps) and 2/3 are short maturities (O/N, 1M, 3M, 1Y). Additionally, the length of the reinvestment (maturity) also depends on bank's strategies – marketing, gaining clients at all costs, liquidity needs and the margin requirements.

Current accounts do not have a known maturity as savings accounts do, but a bank can consider current accounts as a stable and predictable source of funding due to following reasons: first, balances on savings accounts are predictable as clients use current accounts as transactional accounts, i.e. they always maintain balance there to cover their short-term liquidity needs. Second, the interest rate on current accounts is almost zero. Third, clients usually have wages delivered to current accounts, i.e. a balance on current accounts follows a simple and predictable pattern from one wage delivery to another wage delivery. As a result of this predictability, a bank is able to determine the core of current accounts relatively easily and this core can be reinvested.[8] The margin from the reinvestment of current accounts is stable, high and to a certain extent interest rate insensitive. On the contrary, the margin from savings accounts is lower, volatile and interest rate sensitive.

The risk management of term deposits is straightforward as term deposits are instruments with a known (contractual) maturity. A bank invests term deposits into instruments with the same maturities as is the maturity of term deposits. A margin from term deposits is stable and predictable as at maturity, a bank receives a known coupon from the reinvestment and pays the lower known term deposit rate to the client. On the contrary, savings accounts do not have a contractual maturity. Therefore, a bank has to estimate it either by the replicating portfolio approach or by other methods. This estimation is always prone to model risk, resulting in the unsure margin from savings accounts.

Table 3.1: Comparison of savings accounts, term deposits and current accounts

	Savings accounts	Current accounts	Term deposits
Reinvestment risk	Higher	Lower	None
Notice period	None	None	Yes
Interest rate sensitivity	Higher	Lower	None
Stability of volumes	Lower	Higher	High
Marketing strategies	High	Low	Moderate
Margin and its stability	Low	High	High

Source: Author

[8] The core of current accounts is reinvested into long-term maturities, usually long-term government bonds with maturity of 10 or 15 years.

We summarize that margins from savings accounts are unstable due to the interest rate risk (deposit rates often change due to competition and acquisition of clients) and instability of deposits, which further exposes a bank to liquidity risk. Figure 3.1 shows that under increasing market rates, competition in deposit rates offered on savings accounts will lead to decreasing and even negative margins from the reinvestment position. The loss for banks resulting from the interest rate risk happened in the past. For example, the Savings and Loan crisis of the 1980s and 1990s in the US is seen as a direct consequence of the interest rate risk (BCBS, 2004). Due to evident exposure to the interest rate risk, we focus on this type of risk. We derive that banks entering the market during low markets rates are more exposed to low and negative margins than well-established banks due to the fact that established banks have a part of their replicating portfolio in long-term instruments from high market rates periods and only rolls over a part of the portfolio at low yields. However, new banks have to start to construct their portfolios only with instruments bearing low yields.

4 Models behind the Risk Management of Savings Accounts

This thesis aims to estimate the interest rate risk of savings accounts in different types of banks as well as in the whole sector in the Czech Republic. The estimation of the interest rate risk using the static replicating portfolio approach requires defining four models: (i) the market rate model, (ii) the deposit rate model, (iii) the model describing the dynamics of volumes, and (iv) the replicating (reinvestment) portfolio model. This chapter is centered on the description of these models. It also provides empirical results in the case of (i), (ii) and (iii). The results from the replicating (reinvestment) portfolio and the outcome of our analysis are then derived in the following section 5.

4.1 Three Types of Banks

We identified three types of banks in the Czech Republic. These types are:

(i) ***The low-cost bank.*** During the last 5 years, many new banks have entered the market. Those new banks intend to distinguish themselves from the well-established banks by offering low-cost products. They often offer a better deposit rate than the well-established banks and keep lower or none maintenance fees for account operations (zero fee policy). These banks build their business on the basis that the client can manage her account entirely through a mobile phone or the internet, which is promoted as a client-friendly environment. Another feature common to these new banks is the fact that they offer fewer products than the well-established banks. Their product base usually consists of one or more savings accounts products, current accounts, consumer loans, and in some cases mortgages and term deposits.[9] We observe that new banks focus on savings accounts, which is apparent from

[9] In Bubák (2013b) the director of ZUNO bank states that ZUNO will not focus on increasing the product base in 2013. This may indicate that new banks will not be interested in enriching products base either because it is costly or because they consider their products on offer are sufficient to attract clients (Tůma, 2013).

their marketing campaigns and the increasing importance in banks' liabilities. We find that new banks are dependent on savings accounts as they can in extreme case amount up to 90% of their liabilities[10] and represent the main source of funding and deposits. This directly means that new banks (some, not all of them[11]) have a lower share of deposits on current accounts in total liabilities when compared to the well-established banks. This is of importance. In section 3.2.2 we describe that the margin from current accounts is stable and substantially larger than the margin from savings accounts. Some new banks that have few current accounts' liabilities therefore lack an important source of interest income.

In the following text, we refer to such banks as to *the low-cost bank*s. Low-cost means that clients pay almost no fees to a bank as well as a bank having lower expenses due to few client centers and products on offer. Typical examples of *the low-cost bank*s are Air Bank, Equa bank, mBank, and Zuno. The typical client of a *low-cost bank* is the interest rate sensitive "active" client that pursues the best deposit rate offered on the market, which raises instability of savings account' deposits in *the low-cost bank*s. Due to this, *the low-cost bank*s need to attain relatively high deposit rates on savings accounts as compared to the well-established banks; a high deposit rate is the most important factor that attracts and retains their clients.

Maes and Timmermans (2005) and Dewachter, et al. (2006) argue that medium-sized banks in Belgium have on average a higher deposit rate than large banks. We observe a similar situation in the Czech Republic. However, savings deposits are subject to regulation in Belgium; for example, there is a

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[10] For example, Air Bank reports to raise its liabilities from CZK 2.3 billion to CZK 31 billion during 2012. Given the fact that only CZK 26 million from CZK 2.3 billion in 31 December 2011 and CZK 458 million in 31 December 2012 were placed on current accounts, we can conclude that (i) a majority of Air Bank deposits were savings accounts as of 31 December 2011 and (ii) deposits in Air Bank increase significantly. Moreover, Equa bank also reports significant increases in its liabilities.

[11] We cannot directly obtain the share of current and savings accounts in banks' liabilities as these are usually reported together under the category of deposits available on demand.

cap on the deposit rate.[12] There is no such regulation in the Czech Republic and therefore, banks may adjust their deposit rates without any limits.

ii) ***The traditional bank***. A *traditional bank* is a well-established bank that offers a large variety of standard banking products, such as current accounts, term deposits to households and corporates, investment funds, pension funds, advisory and more. In other words, *the traditional bank* reports a more diversified funding than *the low-cost bank*. Examples of *the traditional bank*s include ČSOB, Česká spořitelna, Komerční banka, Raiffeisenbank, or UniCredit Bank. Clients are usually more loyal to *the traditional bank* as they tend to have more than one product there and also because *the traditional bank* can offer them a wide portfolio of services and products. As a consequence, this loyalty implies higher stability of deposits in *the traditional bank*. Last but not least, *the traditional bank*s usually charge higher fees compared to *the low-cost bank*s, which represents an important source of income.

iii) ***The third type bank*** is a residual category since not all banks can be considered to be either as *the low-cost* or the *traditional bank*s.

We highlight that banks are not only institutions providing savings accounts. There are numerous financial institutions such as *družstevní záložny* a *kampeličky* in the Czech Republic. Tůma (2013) documents that these institutions provide on average a higher deposit rate than banks, even *the low-cost* ones, while also reporting higher consumer loans in defaults than is common for banks. However, in our thesis, we focus solely on the risk management of savings accounts in banks as the volumes deposited in institution other than banks are low. Nevertheless, we stress that the risk management of savings accounts in institutions other than banks in the Czech Republic raises concerns and should be treated accordingly by the regulator.

4.2 Models behind the Risk Management and their Calibration

To define a replicating portfolio, a bank needs the market rate model, which defines the term structure of interest rates, the deposit (client) rate model,

[12] The deposit rate is a combination of a base rate that cannot exceed 3% or ECB refinancing rate and the loyalty premium that that shall be in the interval of 25% - 50% of the base rate.

which defines the interest expense, and the volumes model, which defines balances available for the reinvestment. In this section, we describe and calibrate these models. In section 5 we then estimate the interest rate risk of savings accounts by (i) random simulations and (ii) stress tests with 6 scenarios for the market rate.

4.2.1 The Data

Before we describe our models, we briefly describe sources of our data. We have two sources of the data: (i) freely available data from the Czech National Bank (ARAD time series database), ING Bank, individual webpages of banks, our own dataset of deposit and (ii) CZK swap rates and the data for the deposit rate and savings accounts' volumes from an anonymous bank located in the Czech Republic, referred to as the Bank.

4.2.2 The Market Rate Model

There are numerous interest rate models and their full listing is behind the scope of this thesis. Therefore, we focus mainly on interest rate models that were used by authors who modeled dynamics of non-maturing liabilities. Each interest rate model has its advantages and disadvantages and is adequate for fitting different series. Authors tend to use different models; many of them, for example, Brigo, et al. (2007) use the Vašíček (1977) model or the CIR model. On the other hand, Kalkbrener and Willing (2004) find that the two-factor Vašíček model does not adequately fit their data, and better calibration results were obtained by non-parametric HJM models. Nystrom (2008) also uses some extension of the Vašíček (1977) model, or more precisely of the Hull and White (1990) model, as the mean-reversion parameter is time dependent. Frauendorfer and Schurle (2006) fit the market rate to the two-factor Vašíček model.

In this thesis we opt for the one-factor Vašíček (1977) model, which is one of the most used interest rate models. We calibrate the Vašíček (1977) model to the 2W repo rate, which is identified as a representative market rate in the Czech Republic. We are then, by using calibrated coefficients, able to obtain the term structure of interest rates, which defines yields on different maturities under specific market rates. We stress that the Vašíček (1977) model described below is not solely for the purposes of the interest rate model calibration. For example, the Vašíček (1977) model can be fitted to bond yields, not to the market (interest) rate. On the other hand, when considering savings accounts, changes in short-term market rates directly influence bank's decision about the deposit rate. Therefore, we use the 2W repo rate, not bond yields. The market rate is also used by Kalkbrener and Willing (2004), who note that their intention is not to fit a current market price of plain vanilla instruments, but to obtain realistic development of the market rate. Table 4.1 summarizes relevant studies that aim to find the best fitting model for the interest rate, mainly in the context of savings accounts.

Table 4.1: Summary of relevant studies focused on the market rate modeling in the context of the risk management of non-maturing liabilities as well as independently from it

The author/ authors	The interest rate	The method used	Further notes about the model
Nystrom (2010)	Artificial	Coefficients defined to be in accordance with market knowledge	The model incorporates the possibility to decide whether we want increasing/decreasing market rate.
Kalkbrener and Willing (2003)	German 1M, 3M, 6M, 1Y Libor and swap rates of 2Y, 3Y, 5Y, 7Y and 10Y	The two-factor extended Vašíček (1977) model and the non-parametric model with piecewise volatility function. Estimated by the principal components analysis.	The non-parametric model fits the data the best.
Frauendorfer and Schurle (2006)	Historical time series of short and long maturities	The two-factors extended Vašíček model estimated via maximum likelihood.	
Paraschiv and Frauendorfer (2011)	5Y and 10Y Swap rate and Libor 3M and 6M rate	None. Interest rates themselves not calibrated and only historical time series are used.	Authors use real-world time series as explanatory variables in the model for the deposit rate.
Brigo, et al. (2007)	EMU Corporate A-rated 7-5Y index	The Vašíček (1977) model estimated via the OLS method and maximum likelihood. The CIR model calibrated via maximum likelihood. The exponential Vašíček model calibrated via maximum likelihood.	
Dewachter, et al. (2006)	Monthly Belgian zero-coupon bond yields for several maturities	Latent factor term structure model estimated jointly with other models via maximum likelihood.	

Source: Author

4.2.2.1 The Vašíček Model of Interest Rates and its Calibration

The Vašíček (1977) model is a one-factor differential and continuous expression of a short-term rate that is driven by one factor (in an environment with a constant market price of risk that is independent of time and interest rate - risk neutral probability space) that follows the Ornstein-Uhlenbeck (OU) process proposed by Vašíček (1977):

$$dm_t = a(b - m_t)dt + \sigma dW_t \tag{4.1}$$

In the equation (4.1) m_t is a short-term interest rate, a is the speed at which the interest rate returns to its mean b, σ is volatility at time t. W_t is a Wiener process, which is a random process representing the market risk factor (the only uncertainty in the model). All a, b and σ are strictly positive. The Vašíček (1977) model belongs to equilibrium models as it assumes that in the long term, the interest rate mean reverts (returns to its mean), which is an observed characteristic of interest rates. To estimate parameters in the equation (4.1) we need to move the continuous expression into a discrete one. The Vašíček model can be discretized as in Brigo, et al. (2007):

$$m_t = A + Bm_{t-i} + \delta z_t \tag{4.2}$$

In the equation (4.2) we model the change of the market rate in time between t and t-i, where dt=t-(t-i) is a constant change in time, z_t is white noise with N(0,1) and δ is its volatility. The equation (4.2) is a simple AR(1) process. When a>0 and 0>B>1, then (4.2) is stationary and mean-reverting to b. Parameters A, B and δ can be estimated by the maximum likelihood method (MLE) as well as via the OLS method. As the Vašíček process is an OU process, both the OLS method as well as the MLE method provide the same results. OLS estimators of the parameters in (4.2) are thus MLE (Brigo, et al., 2007). We employ the MLE estimation in our analysis. For the derivation of MLE estimators of a, b and σ, we use estimators in Brigo, et al. (2007). The parameters a, b and σ are then derived from A, B and δ as follows:

$$A = b\left(1 - e^{-adt}\right) \qquad B = e^{-adt} \qquad \delta = \sigma\sqrt{\frac{(1 - e^{-2adt})}{2a}}$$

$$a = -\ln(B)/dt \qquad b = \frac{A}{1 - B} \qquad \sigma = \frac{\delta}{\sqrt{\frac{(B^2 - 1)dt}{2\ln(B)}}}$$

We stress that the Vašíček (1977) model includes the possibility of negative rates. This is considered a flaw by many researchers. However, negative interest rates are theoretically possible when considering real interest rates, while nominal interest rates are lower than inflation. Additionally, negative interest rates are observed, even though extreme, characteristics interest rates. From history we know that periods of negative central bank interest rates occur occasionally, as for example in Sweden in 2009[13] or in Denmark in 2012.[14] Consequently, we attain the possibility of negative interest rates in our analysis of the 2W repo rate, which is also a central bank rate. Although real interest rates can be negative in extreme cases, negative interest rates are not possible for bond yields, i.e. bond yields are always strictly positive as nominal interest rates are always strictly positive. To address the problem of negative bond yields in random simulations of the market rate, we assume that in each case of the negative market rate, we let its value to be zero. By doing so, we avoid the problem of negative interest rates. This simplification is possible due to the fact that negative interest rates in reality would translate in very low bond yields, which is exactly the situation when the rate is zero.

4.2.2.2 The Term Structure of Interest Rates

We define the term structure of interest rates as the yield curve, see Definition 1. The calibrated coefficients a, b and σ uniquely define the term structure of the interest rate m_t in time T from the time interval (t,T). In other words, the yield curve for pure-discount instruments consisting of annualized yields is derived from this interest rate at each moment in time using the following set of equations from Brigo and Mercurio (2001), under suitable choice of market price of risk:

$$\begin{gathered} \mathrm{B(t,T)} = \frac{1}{\mathrm{a}}\left[1 - e^{-\mathrm{a(T-t)}}\right] \\ \mathrm{A(t,T)} = exp\left\{\left(\mathrm{b} - \frac{\sigma^2}{2*\mathrm{a}^2}\right)[\mathrm{B(t,T)} - \mathrm{T} + \mathrm{t}] - \frac{\sigma^2}{4\mathrm{a}}\mathrm{B}^2(\mathrm{t,T})\right\} \\ \mathrm{yield(t,T)} = -\ln\left[\mathrm{A(t,T)}e^{-\mathrm{B(t,T)m_t}}\right]/\mathrm{T} \end{gathered} \tag{4.3}$$

The yield curve yield(t, T) constructed from A(t,T) and B(t,T) defines annualized yields for instruments maturing from time t to T. It represents the set of bank's investment opportunities with different maturities at time t. Usually, the yield curve is upward sloping, i.e. long maturities have a higher yield than short maturities. The yield curve derived from the equation (4.3) is upward sloping

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[13] In 8 July 2009 Riksbank cut down the central bank overnight deposit rate (rate at which banks can/must deposit funds in Riksbank overnight) to -0.25%. The rate remained negative until 7 July 2010.

[14] Since 6 July 2012 Denmark Nationalbank decreased the certificate of deposit rate to -0.2%. As of 31 March 2013, the rate remains negative at -0.1%.

whenever the current market (spot) rate at time t is below its long-term average. If the market (spot) rate is higher than its long-term average, than the yield curve will be downward sloping - short-maturities will have higher yields than long ones. Downward sloping yield curves are unusual, but can occur.

The yield curve constructed from market rates (the spot rate) includes swap rates for all maturities, not bond yields. We find that 10Y CZK currency swap is close to the 10Y government bond yield, even though it sometimes differs more and swap is usually lower. In the following analysis, we define that a bank reinvests savings accounts deposits into money market instruments and government bonds. This means that we approximate bond yields with maturities higher than one year derived from the equation (4.3). This is common procedure in all papers we analyzed. Theoretically, a replicating portfolio consists of zero-coupon instruments derived from the equation (4.3). In reality, banks reinvest into government bonds, short-term money market instruments and long-term swaps.

4.2.2.3 Empirical Analysis of the 2W Repo Rate and the Derivation of Yields from the Yield Curve

For reasons that will be discussed in detail in section 4.2.3.1, we use the 2W repo rate as a benchmark market rate in the Czech Republic. The values of parameters a, b and σ were obtained by the calibration of historical daily values of the 2W repo rate from 1 January 1999[15] to 28 February 2013.[16] It is also possible to directly use the values of a, b and σ from the historical time series. However, as we obtain estimates in accordance with the original series, we decided to rather calibrate series than to derive parameters directly from the series. The 2W repo rate is found to be a stationary series on this sample (the ADF test statistic with constant and 9 lags is -4.85 which falls below 1% critical value of -3.43 as well. This allows us to reject the null hypothesis of the unit root presence.). As the mean-reversion is not rejected, we can calibrate the 2W repo rate using the Brigo et al. (2007) procedure described above. The calibrated

[15] The period before 1999 is excluded due to unprecedented volatility.

[16]

Summary Statistics for 2W repo rate from 1 January1999 to 28 February 2013

Mean	Median	Minimum	Maximum
0.027745	0.025000	0.00050000	0.095000
Std. Dev.	C.V.	Skewness	Ex. Kurtosis
0.018410	0.66355	0.82399	0.19338

market rate model is as follows: $d\mathrm{m_t} = 0.44(1.31\% - \mathrm{m_t})dt + 0.063d\mathrm{W_t}$.[17] Parameter b = 1.31% is the estimated mean value of the 2W repo rate, which slightly underestimates the true mean value of the sample, but has no significant impact on the final outcome of our analysis due to even distribution of the reinvestment. In the first step of the calculation of the yield from the reinvestment, we do not calculate those yields using the equation (4.3). We rather use average monthly observable values of PRIBOR rates and government bonds from 31 March 2013 as is the common practice. We highlight that the calibrated model has a tendency to underestimate true long-term market yields for rapidly increasing market rate. This stems from low estimated mean value, which is a direct consequence of low average repo rate of 1.5% during recent years.

For simulations, we use the discretized version of the equation (4.1) in the form of: $\nabla \mathrm{m_t} = \mathrm{a}(\mathrm{b} - \mathrm{m_{t-1}})\nabla \mathrm{t} + \delta\sqrt{\nabla t}$ and to derive yields, the equation (4.3) is used. For scenarios (stress testing), we define the market rate development as a gradual increase and use only calibrated coefficients and the equation (4.3) to derive yields. Calibrated parameters are in their annual value, which implies that we can simulate monthly steps as our analysis requires. To do so, we let dt = 1/12. The initial value of the market rate for both simulations and scenarios is 0.05%, i.e. the 2W repo rate value from 31 March 2013.

4.2.3 The Deposit Rate Model

The development of market rates is one of the most important driving forces in the development of deposit rates. Banks adjust deposit rates to market rates to account for changes in the margin gained from the reinvestment as well as to account for marketing and management strategies. The deposit rate on savings accounts is characterized by non-linear adjustments. For this reason, Paraschiv and Frauendorfer (2011) and Blochlinger (2010) point out that a linear model does not neatly fit the deposit rate and propose different models - among these are asymmetric adjustment models, friction models, probit models,

[17] We find that residuals are not normally distributed and become autocorrelated after 9th lag. However, we can easily address this as: (i) parameters we obtained are consistent with the market, therefore yields we derive are consistent with real yields and (ii) in simulations we draw random errors from N(0,1) and (iii) the estimation of UO process by OLS can be done by using robust statistics, which results in equal estimates, but not correlated and homoscedastic errors.

error correction models, and others. The adjustment of the deposit rate to market rates is found to be asymmetric and lagged.

Asymmetric adjustment: Under increasing market rates, banks' reaction to adjust the deposit rate is slower than under decreasing market rates. This is due to the fact that under increasing market rates, banks want to exploit the short period of a low deposit rate and a high market rate to maximize their margins. The opposite applies to decreasing market rates. This asymmetric adjustment is documented by Paraschiv and Frauendorfer (2011), Frauendorfer and Schurle (2006), Maes and Timmermans (2005) and also in O'Brien (2000).

Lagged adjustment: Paraschiv and Frauendorfer (2011) mention that the lag in the adjustment of the deposit rate arises from administrative costs. Banks have to compare costs to benefits of the adjustment, and only when benefits exceed costs, banks adjust the rate. Adjusting the deposit rate after every change in the market rate would be too costly. Due to this, banks adjust deposit rates only when market rates change by a significant amount and non-temporarily. The lagged adjustment is sometimes defined as the rigidity of deposit rates and verified by several studies; for example, in Paraschiv and Frauendorfer (2011).

Stepwise structure: Deposit rates do not develop continuously, but in steps with long periods when the deposit rate remains constant. Stepwise structure of deposit rates is a consequence of an asymmetric and lagged adjustment.

There are numerous models for a non-maturing liabilities deposit rate. In Table 4.2 we provide description of these we consider of relevance in the context of savings accounts' modeling.

Table 4.2: The literature review for NML deposit rate models

Author/s	Model	Explanatory variables	The method of estimation	Notes
Blochlinger (2010)	Logit model	Several short and long maturities swap rates and lagged values of the deposit rate	Logit model calibration	The Logit model provides a good fit. Author includes banks' decision behaviour parameters that reflect the strategy under which a bank adjusts the rate. This decision parameters are explained by lagged values of market and deposit rates.
Dewachter, et al. (2006)	Linear model	Deposit rates and market	Maximum-likelihood	Asymmetry not included into the model. Deposit factor captures the

		rates	and the Kalman filter	spread between deposit rates in medium-sized banks found to be on average higher than in large banks.
Frauendorfer and Schurle (2006)	The threshold model	Lagged value of deposit rate, current and lagged observations of market rate factors	Maximum likelihood	The deposit rate explained by level factors of market rates that were obtained from the calibration of the two-factor Vašíček model. When the deposit rate reaches threshold, the adjustment occurs. The model includes the asymmetric characteristic.
Kalkbrener and Willing (2004)	Linear model	Several short and long market rates and swap rates	Calibration to the historical data	
Maes and Timmermans (2005)	Non-linear partial adjustment model	The lagged value of implicit deposit rate, the unobserved time-varying equilibrium deposit rate (that is a function of the EURIBOR 3M) and the dummy variable indicating whether observed implicit deposit rate is above or below long-run equilibrium	Non-linear regression model	The implicit rate is calculated as the interest expense divided by average outstanding balances. Authors argue that implicit rate better characterize true cost of a bank. Deposit rates are found to adjust asymmetrically. Model similar to O'Brien (2000).
Nystrom (2010)	Adjustment model	Simulated market rate	Simulations	The deposit rate is simply explained as some % of the market rate.
O'Brien (2000)	Asymmetric partial adjustment model	Treasury bill 3M	Non-linear least squares	The author stresses that true adjustment is less regular than is estimated by the model.
Paraschiv and Frauendorfer (2011)	Error-correction model	Lagged values of 5Y swap rate, LIBOR3M and the deposit rate	The OLS method	Authors stress that linear model is not able to capture shocks in the observed average deposit rate across Swiss non-maturing accounts.
Paraschiv and Frauendorfer (2011)	Threshold model in the error-correction form	Lagged values of 5Y swap rate, LIBOR3M deposit rate, threshold variable and the error correction term	Lagrange multipliers and the Least squares	Authors find an evidence of rigidity of deposit rates The strong asymmetric relation between changes in the deposit rate and a long-term market rate is also found. Authors argue that the threshold model in the error-correction form is able to capture shocks in the observed average deposit rate.
Paraschiv and Frauendorfer (2011)	Friction model	Swap 5Y, Swap 10Y, LIBOR1M and LIBOR3M	Maximum likelihood	The friction model is able to capture both asymmetric adjustment, stepwise structure as well as the lag in the adjustment. It is found that adjustment downwards happens more quickly than the adjustment upwards.

Source: Author

4.2.3.1 Relations between Market Rates and Deposit Rates - the 2W Repo Rate as a Benchmark Rate

We recall that the focus of our analysis is the savings accounts' competitive environment. Several banks in the Czech Republic, mainly so-defined *low-cost bank*s, compete for liquidity and depositors. These banks are expected to react more quickly to changes in the 2W repo rate than *the traditional bank*s. A quicker reaction leads to a decreasing lag in the deposit rate adjustment, as well as to decreasing asymmetry in the upward adjustment as *the low-cost bank*s will increase deposit rates more quickly and more often. On the contrary, the adjustment downwards is more lagged due to competitive pressures, especially in the case of *the low-cost bank*s.

Due to the lack of data,[18] we have closely analyzed only two deposit rates. These are the ING deposit rate and the deposit rate in the anonymous bank, the Bank. Both series are in monthly values. The deposit rate in the Bank spans from 1 July 2007 to 31 December 2011[19] and the ING deposit rate from 1 January 2002 to 31 December 2012. We analyze both these deposit rates to define a deposit rate model. Results of this analysis are included in detail in Appendix 8.1; here we focus only on the most important features. We find that during high market rates, deposit rates are below the 2W repo rate. The opposite applies for low market rates. Since November 2008, both ING deposit rate, as well as the deposit rate in the Bank, are above the 2W repo rate. Furthermore, Figure 2.5 shows that all rates offered on savings accounts since 2011 are higher than is the current 2W repo rate of 0.05%. Evidently, banks are reluctant to follow the 2W repo rate with the adjustment of deposit rates downwards, even though decreases in deposit rates[20] happen as market rates stay at historically minimal values. This indicates that deposit rates are sticky downwards.

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[18] We face the lack of individual banks' data either because it is not available or because time series are too short.

[19] The data by the Bank was provided until 2011. Therefore, we do not possess monthly deposit rates during 2012; more precisely we do not known in which months or days a bank was decreasing a rate. However, we know that that the deposit rate in the Bank was 1.6% in January 2012 and 1.5% since August 2012 to December 2012. In January 2013, the Bank decreased the rate to 1.3%. The swift decrease to 1.3% results from low market rates.

[20] See section 2.4.2.

It is usually found that market and deposit rates are strongly correlated. Our analysis of the correlation of monthly values of the deposit rate in the Bank and the ING deposit rate with several market rates (monthly averages of PRIBOR[21] rates, government bonds and swap rates) is in detail provided in Appendix 8.1.[22] We find that during 1 July 2007 - 31 December 2011 the deposit rate in the Bank is strongly positively correlated with the 2W repo rate, all short-term PRIBOR rates, as well as with the 1Y currency swap. It is the most strongly connected to PRIBOR3M, and PRIBOR3M is very closely related to the 2W repo rate. As all PRIBOR rates are correlated with one another, we can take the PRIBOR3M rate as a representative rate for all PRIBOR rates. Neither currency swap is correlated as strongly as PRIBOR rates and the 2W repo rate to the deposit rate in the Bank. We also calculated correlations between PRIBOR rates, the 2W repo rate and the deposit rate offered on ING savings accounts from 1 January 2002 to 31 December 2012. We find that the ING deposit rate is more correlated to longer maturities than to shorter ones (the closest connection is to PRIBOR9M). The ING deposit rate is also strongly correlated to the 2W repo rate.

We also find that the 2W repo rate and both deposit rates develop in discrete steps, whereas the PRIBOR rates development is more continuous. As stated above, stepwise structure is a common feature of savings accounts' deposit rates. This indicates that the 2W repo rate, even though being slightly less correlated with the both deposit rates than PRIBOR rates, is a better explanatory variable for the deposit rates in general than PRIBOR3M. Furthermore, we aim to find a model for all deposit rates offered on savings accounts. The close connection of the deposit rate in the Bank to PRIBOR3M may

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[21] PRIBOR rate is a rate at which banks are willing to provide loans to other banks. PRIBID is a rate at which banks are willing to take deposits from other banks. Both rates are important, influence deposit rates and interest rates on loans.

[22] We stress that the correlation analysis is sufficient for our deposit rate model presented below. The common procedure of the estimation of the relation between deposit rates and market rates would also require the estimation of cointegration to ensure that market rates and selected deposit rates are cointegrated or not (usually will be, as for example in Paraschiv and Frauendorfer (2011)). However, we do not employ estimation methods such as VAR of Error correction model that would require deeper knowledge behind the long run relations of deposit rates and market rates, which in turn means that cointegration analysis is redundant.

come from the Banks' reinvestment strategy, which is not common for all banks; we find that the ING deposit rate is the most correlated to PRIBOR9M. We stress that the best way to derive the general model would be an aggregate deposit rate. However, this is not possible for the Czech Republic due to unavailability of the data, short-time sample and uneven distribution of new banks entering the market that would bias the estimation.

Owing to evident strong connections between both deposit rates and the 2W repo rate, we select the 2W repo rate as a benchmark rate in the deposit rate model:

- The 2W repo rate is strongly correlated to all short-term market rates.
- The 2W repo rate develops in discrete steps as well as deposit rates do.
- The 2W repo rate is a "known" value to the average client. It is more probable that the average client knows the 2W repo rate value than other short-term rate values. An average and interested/active client follows the development of the 2W repo rate and when her bank does not reflect changes in the 2W repo rate, especially upward ones, she starts to pay attention to different savings accounts providing higher rate of return. In other words, the 2W repo rate development is of importance in banks' adjustment strategies. For example, Air Bank and ING in November 2012 announced a decrease in the deposit rate as a result of a decrease in the 2W repo rate.
- We have identified that banks adjust the deposit rate when the difference between the 2W repo rate and the deposit rate reaches some predefined threshold.
- We have identified that the correlation between different deposit rates and market rates always differs for different deposit rates, i.e. some deposit rate is more connected to PRIBOR3M and other to PRIBOR9M. Therefore, selecting one short-term rate based on the deposit rate in one bank would bias the development of the deposit rate in other bank. On the other hand, the 2W repo rate is strongly correlated to all market rates.

- Central bank rates are used in the estimation of dynamics of deposit rates by some authors (Paraschiv, 2011).

4.2.3.2 The Deposit Rate Model

To our best knowledge, we are the first to use the asymmetric adjustment or friction model in the form described below on Czech data. Our model is similar to the asymmetric adjustment models proposed by Paraschiv and Frauendorfer (2011), Kalkbrener and Willing (2004), Maes and Timmermans (2005) and Frauendorfer and Schurle (2006), but our model in certain aspects differs from those models due to unique market characteristics in the Czech Republic. As we described in the theoretical part of the study, new banks have recently entered the market with savings accounts. These new banks aim to beat the market of more established savings accounts offered by the well-established banks. This raises competitive and risk pressures among banks. We identified three types of banks among Czech banks. Each type of a bank has certain characteristics and these are basic factors around which our deposit rate model is built. Based on these characteristics, we define banks' adjustment strategies of the deposit rate in the following manner:

- *The traditional bank* is expected to adjust the deposit rate in the same fashion as was documented by Paraschiv and Frauendorfer (2011), Maes and Timmermans (2005) and Frauendorfer and Schurle (2006), i.e. it is less willing to increase the rate when market rates increase and it is more willing to decrease the rate under a prevailing decrease in market rates. *The traditional bank* can bear the loss of deposits as it has a strong base of other depository products, mainly low deposit rate bearing current accounts.

- *The low-cost bank* bids aggressively for clients (liquidity) by offering high deposit rates. We define exactly the opposite asymmetric reaction to the adjustment of the deposit rate in *the low-cost bank* as compared to *the traditional bank*s. *The low-cost bank* under increasing market rates reacts more quickly with an adjustment than under decreasing market rates. *The low-cost bank* has to follow increases in the market rate not to lose active clients (since a majority of its clients are active ones) as it depends on their deposits. The same applies for downward movements; *the low-cost bank* is less willing to decrease the rate as the loss of savings accounts' deposits is crucial.

- *The third type bank* represents banks between *the traditional* and *the low-cost* ones. Its adjustment strategies lay thus between the two strategies mentioned above.

To account for competition and banks' strategies described above, we define the deposit rate model as follows:

$$
\begin{gathered}
\nabla c_{i,t} = \rho_i \quad \text{if } \left|c_{i,t-1} - m_t\right| \geq \alpha_i \text{ and } \ (m_t - m_{t-1}) > 0 \text{ and } \ m_t > 0 \\
\nabla c_{i,t} = -\tau_i \quad \text{if } \left|c_{i,t-1} - m_t\right| \geq \beta_i \text{ and } \ (m_t - m_{t-1}) < 0 \\
\nabla c_{i,t} = 0 \ \text{ if } \left|c_{i,t-1} - m_t\right| < \beta_i \text{ and } \ (m_t - m_{t-1}) < 0 \\
\nabla c_{i,t} = 0 \ \text{ if } \left|c_{i,t-1} - m_t\right| < \alpha_i \text{ and } \ (m_t - m_{t-1}) > 0 \\
\nabla c_{i,t} = 0 \ \text{ if } (m_t - m_{t-1}) = 0 \\
c_{i,t} \geq \mu_i, \beta_i \geq \alpha_i > 0 \\
i = The\ traditional\ bank, the\ low-cost\ bank, the\ third\ type\ bank
\end{gathered}
\tag{4.4}
$$

In the equation (4.4) $c_{i,t}$ is the deposit rate and m_t is the market rate. The parameter ρ_i defines the adjustment upwards in each bank and τ_i defines the adjustment downwards. The parameter α_i is the threshold value that defines the maximum limit of the absolute difference between the deposit rate and the market rate in each bank during increasing market rates. The parameter β_i is the threshold value that defines the maximum limit of the absolute difference between the deposit rate and the market rate in each bank during decreasing market rates. The bank adjusts the market rate when this limit is exceeded. Finally, μ_i is the downward limit value for the deposit rate in the bank. We include this downward restriction to reflect characteristics of savings accounts offered in the Czech Republic. As the current situation shows, even though the market rates are minimal, banks still hold significantly higher (over 1% to 2.1% as of 31 March 2013) deposit rates. Due to this, we cannot allow the deposit rate to drop below the downward restriction. Under prevailing low adjustments of the market rate downwards, the deposit rate could hypothetically get to almost zero, which would not be consistent with the reality we observe.

We also include the condition that for the upward adjustment α_i, the market rate must be higher than 0 ($m_t > 0$). As historical evidence shows, negative real interest rates may happen. Accordingly, we retain the possibility of negative interest rates in our model for the market rate. Nevertheless, without the condition $m_t > 0$ for an upward adjustment, we would obtain a model in which banks would increase the rate by ρ_i even with the market rate below zero, which is, by all means, improbable. When applying the condition $m_t > 0$, we ensure that banks react to increasing market rates only when market rates are positive.

Parameters ρ_i and τ_i represent the asymmetric adjustment feature of the deposit rate. Parameters α_i and β_i ensure that different banks have different elasticity in response to changes in the market rate. Our model is thus able to account for asymmetric and discrete adjustment in general, as well as for different speed of adjustment in different banks.

Due to the lack of data, we derive exact values of all parameters in the equation (4.4) from the historical data only for the deposit rate in *the traditional bank*s, represented by two deposit rates: the Bank's and the ING Konto's deposit rate.[23] We derive these parameters simply by comparing average differences between deposit rates and the 2W repo rate, as well as the average adjustment of both rates upwards and downwards.[24] For results of these values, see Table 4.3. The rest of parameters, i.e. those for *the low-cost bank*s and *the third type bank*s, are derived hypothetically for the purposes of reflecting characteristics we impose on these types of banks. Nevertheless, when setting up values of parameters from the equation (4.4) for *the low-cost bank* and *the third type bank*, we also use marketing strategies and the deposit rate development in other banks so that our model is as close to reality as possible.

As Table 4.3 shows, *the traditional bank*s (represented by ING and the Bank) adjust the deposit rate when the difference between the market rate and the deposit rate for both an increasing and decreasing 2W repo rate is more or equal to 100 bps. Therefore, we find that for *the traditional bank*s, $\alpha_i = \beta_i$. From the historical data we also derive that average decreases τ_i are 30 bps and average increases ρ_i are 25 bps. During 1 January 2012 - 31 March 2013, the deposit rate

[23] We do not include more deposit rates offered on savings accounts in the Czech Republic owing to: a) the lack of data and b) the majority of new savings accounts are on the market for two or less years, which provides very short data samples.

[24] We find that this simple set up is the best and sufficient approach to our analysis. The model could also be, after minor changes and adjustments, calibrated by non-linear least squares or MLE estimation (in the case of the aggregate data as in Paraschiv and Frauendorfer (2011). Probit estimation could also be used, but would require substantially larger aggregate data sample. Therefore, our model can be used for further analysis.

among *the traditional bank*s varies from 1% to 1.5% in a majority of cases. Therefore, we set the downward restriction for *the traditional bank*s μ_i equal to 1%. Figure 8.2 in Appendix 8.1 shows the fit of our model to the deposit rate in the Bank and the ING deposit rate. Our general model provides a good fit, mainly for the Bank. There are periods when our modeled deposit rate differs from the observed values significantly. This is due to sudden large changes in deposit rates, which depend on a sudden and temporary change in the adjustment process in both banks, i.e. banks suddenly decide to adjust the rate by more or less than 25/30 bps. Our model is able to fit the development of deposit rates in the Bank as well as in ING bank, which is our aim. To make *the traditional bank* less elastic to changes in the market rate, when this is very low and close to zero, we let *the traditional bank* to adjust the deposit rate only if the market rate is higher or equal to 1%. Thus we ensure that *the traditional bank* increases the deposit rate only if market rates increase sufficiently to cover the increase in the deposit rate. This reluctance is observed characteristics of deposit rates in the well-established banks and needs to be included in the model.

Table 4.3: The derivation of parameters for the deposit rate model in *the traditional bank*

	The Bank	**ING**	***The traditional bank***
The average difference between the deposit rate and the increasing 2W repo rate for which a bank adjusts the deposit rate	116 bps	58 bps (78 bps if only after 2007)	100 bps
The average difference between the deposit rate and the decreasing 2W repo rate for which a bank adjusts the deposit rate	119 bps	75 bps (116 bps if only after 2007)	100 bps
The average difference between the deposit rate and the 2W repo rate for which a bank adjusts the deposit rate	118 bps	66 bps (95 bps if only after 2007)	100 bps[25]

[25] We stress that the average difference (of both banks) between the deposit rate and the 2W repo rate derived from 118 bps and 66 bps would be 92 bps. However, we define it as 100 bps for *the traditional bank*. This is due to the fact that the adjustment strategy in ING differs until 2007 and after 2007. As we consider of greater importance a later period when ING bank faces competition as more savings accounts are on offer, we opt for 100 bps.

The average magnitude of the adjustment upwards	38 bps (23 bps if an outlier of 80 bps excluded)	20 bps	25 bps
The average magnitude of the adjustment downwards	24 bps	36 bps	30 bps

Source: Author's own calculation based on www.ing.cz, www.cnb.cz and the Bank. The calibration of the data (monthly values of the 2W repo rate since 1 January 2002 to 31 December 2012, monthly values of deposit rate in ING bank since 1 January 2002 to 31 December 2012 and monthly values of the deposit rate in the Bank since 1 July 2007 to 31 December 2011) was done simply in excel by obtaining average values of changes in deposit rates and the average difference between the deposit rate and the 2W repo rate. The adjustment in *the traditional bank* is defined as the average of adjustments in both banks with higher importance of 2007 and later period + stylized facts about adjustment strategies. Therefore, the parameters derived for *the traditional bank* are not exact averages derived from ING and the Bank. The interested reader may also notice that both ING and the Bank are slightly more sensitive to increasing market rates, which contradicts stylized facts. However, given the data, this sensitivity is very low and can be easily explained by the competitive environment in the Czech Republic.

Considering adjustment parameters τ_i and ρ_i in *the low-cost bank*, we define them as the exact opposite of the well-documented interest rate adjustment behaviour in the well-established banks. The pure *low-cost bank* is heavily dependent on savings accounts and is therefore more sensitive to market rate increases than decreases. *The low-cost bank* has to signal to its clients that it is different than other banks, i.e. it adjusts the rate upwards sooner and more often when market rates increase and decreases the deposit rate less and later than *the traditional bank* when market rates decrease.

To summarize, we define that *the low-cost bank* in our analysis adjusts the deposit rate when the difference α_i between the market rate and the deposit rate for increasing market rate is more or equal to 50 bps and that the magnitude of the adjustment upwards ρ_i is 30 bps. We define the threshold α_i value to be lower than for *the traditional bank* to reflect that *the low-cost bank* adjusts the rate with higher sensitivity to the market rate increases than *the traditional bank*. We argue that 50 bps is a meaningful value; as soon as the repo rate starts to increase; *the low-cost bank*s must be the first ones increasing deposit rates. Since October 2012, the repo rate is 0.05% and the average of the three highest rates offered on savings accounts was around 2.3% during August-December 2012, 2.2% during January-February 2013 and 2.1% during March 2013. It means that as soon as the repo rate starts to increase, *the low-cost bank* will increase the deposit rate as the difference between the deposit rate and the market rate is already higher than 50 bps. One may argue that *the low-cost bank* will not increase the deposit rate as soon as the market rate starts to increase due to the fact that the deposit rate around 2% is already high when compared to market rates. Still, in a competitive environment, at least one *low-cost bank*, the one with strong liquidity needs, will increase the rate.

Under prevailing decrease in market rates, we define that that *the low-cost bank* in our analysis adjusts the deposit rate when the absolute difference β_i between the market rate and the deposit rate for the decreasing market rate is more or equal to 200 bps. We argue that this value is observable in the market as repo is almost zero and many banks during 2012 and the beginning of 2013 offer rates around 2%. We define average decreases τ_i to be 20 bps. For example, Air Bank decreased the rate from 2.5% to 2.4% in November 2012, following the decrease of the 2W repo rate by 25 bps in October 2012. In January 2013, Air Bank further decreased the deposit rate by 30 bps to 2.1% and the same as of 19 March 2013 to 1.8%. Due to prevailing low rates since January 2013, other small banks (*the low-cost bank*s) decreased deposit rates as well. Equa bank decreased the rate by 20 bps, Axa Bank by 30 bps and Zuno by 20 bps. Based on this, we derive that the average value of decreases in small banks is around 20 bps, which is less than for *the traditional bank* and consistent with our assumptions. The downward restriction for the deposit rate in *the low-cost bank* is defined as 2% - the three highest rates among banks' savings accounts in the Czech Republic are over 2% in 8 March 2013 and the market rate is almost zero, hence 2% value is a meaningful value.[26]

We summarize parameters for the adjustment process in all types of banks in Table 4.4. Initial values at which we start to simulate the deposit rate using (4.4) in all types of banks are also included in Table 4.4 and were derived from averages values offered on the market during January - February 2013.[27] Even

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[26] By 19 March 2013, Air Bank decreased the rate to 1.8%. Still, for example Equa bank holds the rate at 2.1% by 31 March 2013 and rates above 2% were common until March 2013, even during low market rates. We stress that the market is developing quickly and we base our analysis on the development until 31 March 2013.

[27] Air Bank = 2.5% until December 2012, 2.4% since September 2013 to January 2013, 2.1% since January 2013 and 1.8% as of 19 March 2013, Equa bank = 2.3% in January 2013 and 2.1%

though since January 2013 deposit rates have been decreasing (Figure 2.5), we stick to the initial values from January - February 2013 as these are already low when compared to the average 2.4%[28] deposit rate offered by the highest bidding banks during 2012. The same values as in Table 4.4 imply for scenario analysis (stress testing).

Table 4.4: Deposit rate model parameters for all three types of banks

	The traditional bank	***The low-cost bank***	***The third type bank***
ρ	25 bps	30 bps	20 bps
τ	30 bps	20 bps	25 bps
α	100 bps	50 bps	75 bps
β	100 bps	200 bps	150 bps
μ	1%	2%	1.5%
Initial value	1.5%	2.2%	1.8%

Source: Author's own calculations

4.2.4 The Dynamics of Volumes

Balances on savings accounts are of extreme importance to a bank as these are pooled into the replicating portfolio and are reinvested into short-term, medium-term and long-term instruments. The bank needs to have at least partial information about possible future development of volumes to be able to construct a replicating portfolio that maximizes margin, while minimizing its variance. Unexpected withdrawals lead to liquidity and market risk pressures as a bank needs to fire sell a part of its portfolio to remain liquid.

It is a well-documented fact that volumes on savings accounts decrease when market rates increase as more attractive investment opportunities arise. The opposite applies for decrease in wholesale market rates. However, these well-known facts are not sufficient for the prediction of future balances. A bank also needs to estimate the impact of several factors such as market rates, spread

since February 2013, and Zuno = 2.3% in January 2013 and 2.1% since February 2013. For more detail on deposit rates see Figure 2.5. Based on these high deposit rates, we set the initial value in *the low-cost bank* as 2.2%. Poštovní spořitelna = 1.3%, ING = 1.5%, other rates vary from 0.4% to 2% → initial value in *the traditional bank* is 1.5%.

[28] For example, Air Bank = 2.5%, later 2.4%, seasonal offerings of 2.5% in ING, 2.3% in Equa bank and 2.9% in Axa Bank.

between market rates and deposit rates, term deposits yields, wholesale market indices, monetary aggregate M1 (inflation), and dummies that account for seasonal effects such as Christmas, after-Christmas sales in January, the 13th wage period and the holiday period in summer. To estimate how these factors influence volumes, a bank can use methods like linear models or the VAR approach. However, the development of balances deposited is still uncertain, as well as the development of factors that influence them. For this reason, a bank always reinvests a part of the portfolio into short-term instruments to sustain unexpected withdrawals up to a certain extent.

In Table 4.5 we provide a literature review of several models that explain balances on savings accounts and non-maturing liabilities in general. Models describing dynamics of volumes can be divided into two classes. The first class consists of models where authors estimate significant factors for changes in volumes using simple linear and VAR models. The second class is more interesting from a simulations point of view as it explains deposit balances by using less factors, usually only market or deposit rates (Due to the collinearity problem, only one market or deposit rate can be included in the model.). This class of models can be further decomposed into models assuming that volumes develop constantly around some trend as in Kalkbrener and Willing (2004) or Frauendorfer and Schurle (2006), and into models including the rate of decay of balances as in Dewachter, et al. (2006).

The Czech National Bank reports data on savings accounts together with current accounts until 31 July 2010. After 31 July 2010, savings accounts were transferred to another category, but still are not reported separately. We therefore cannot assess the aggregate development of savings accounts balances in the Czech Republic, but we are able to extract general trends in the development of volumes of savings accounts from other sources, such as the Bank, entrance of new savings accounts and balance sheets of particular banks of interest. We have data for monthly volumes of savings accounts deposited in the Bank from 31 July 2007 to 31 December 2011. During this time, deposits on savings accounts increased in the Bank from CZK 23 million to CZK 37,216 million, even though the rate of increase have gotten somewhat slower since 31 July 2009. From the Air Bank's balance sheets (for details see Appendix 8.2), we know that balances on deposits payable on notice (majority of them in savings accounts) increased by more than 13,000% from 31 December 2011 to 31 December 2012. From the Equa bank's balance sheets as of 31 December 2011 and 31 December 2012 we derive that liabilities payable on notice (including savings accounts and current accounts) increased by more than 1,500% during 2012. Based on this, we may conclude that in banks that offer the highest deposit rates, deposits increase significantly.[29] During the period of 2009 - 2010, many new savings accounts (Fio konto, mBank, Axa Bank) appeared and during the same time the growth of volumes in the Bank got slower. Therefore, we may also conclude that banks that offer the highest deposit rates do attract some depositors from the well-established *traditional bank*s.

Table 4.5: The literature review for models describing the volumes on NML

Author/s	Model	Explanatory variables	The method of estimation	Notes
Blochlinger (2010)	Linear model	LIBOR and deposit rates	Maximum-likelihood	
Dewachter, et al. (2006)	Linear model	The deposit rate and the withdrawal rate	Maximum-likelihood and Kalman filter	Volumes grow at the deposit rate and decrease at the constant rate of decay.
Frauendorfer and Schurle (2006)	Linear logarithmic model	Time trend and factors from the Vašíček model for the market rate	The OLS method	Constant and time trend reflect that deposits increase in time.
Kalkbrener and Willing (2004)	Linear model and the Ornstein-Uhlenbeck proces	Time trend and the market rate	The OLS method	Volumes are assumed to fluctuate around linear mean-reverting trend.
Maes and Timmernmans (2005)	Linear model	Opportunity cost of having savings deposits is represented by the difference between 3M Treasury Certificate rate in Belgium (net withholding taxes) and the deposit rate.	The robust OLS estimation.	Authors find that deposit balances increase when market rates decrease and the other way round.
O'Brien	Linear model	Lagged value of deposits and income	The OLS method	Lagged value of deposits is the most significant factor.
Paraschiv and Frauendorfer (2011)	Linear model	LIBOR3M, LIBOR6M, swap 5Y, swap 10Y, spread between market rates and the deposit rate, CPI index, M1 monetary aggregate, Swiss Bond Index, Swiss Performance Index, dummies for December/June/July	The OLS method	Swap 5Y rate, dummies of December/June/July and M1 monetary aggregate are significant.

[29] We cannot assess the development of liabilities in many new banks (Zuno, mBank) as their accounts are reported together with their large owners.

Paraschiv and Frauendorfer (2011)	VAR (vector autoautoregression)	LIBOR3M, LIBOR6M, swap 5Y, swap 10Y, spread between market rates and deposit rates, CPI index, M1 monetary aggregate, Swiss Bond Index, Swiss Performance Index, dummies for December/June/July	VAR and impulse responses

Source: Author

4.2.4.1 The Model for Deposit Volumes

We define our model for savings accounts volumes in the similar fashion as Dewachter et al (2006) - we let balances on savings accounts develop in time based on changes in the deposit rate, but we do not include an annual rate of decay as Dewachter, et al. (2006). We argue that models assuming fluctuations around some constant trend, estimated by linear regression, would not describe the realistic development of balances on savings accounts in the Czech Republic due to the following reason: We have identified that savings account volumes grow significantly and we expect this growth to continue as the number of active clients will increase. The market is evidently developing and has not yet reached stability. Due to this, the assumption that volumes on savings accounts develop constantly would not reflect the current and near future situation in the Czech Republic.

We do not possess the data for aggregate savings accounts' volumes in the Czech Republic as these are not reported by CNB. We only have the data for deposits volumes in the Bank, but we find that volumes in the Bank cannot explain aggregate savings accounts volumes development in the Czech Republic.[30] We therefore do not calibrate historical time series of volumes and opt for simplifications. We let each type of a bank to invest CZK 100 million initially and let volumes to grow only by the recapitalization:

$$\nabla \mathrm{V}_{\mathrm{i,t}} = \left(\sqrt[1/12]{1 + c_{i,t}}\right)\mathrm{V}_{\mathrm{i,t-1}} \qquad (4.5)$$
$$\mathrm{i} = \mathit{The\ traditional\ bank}, \mathit{the\ low-cost\ bank},, \mathit{the\ third\ type\ bank}$$

[30] Dynamics of volumes in the Bank cannot be used to explain volumes in other banks as well as aggregate volumes due to: (i) in different banks volumes grow differently based on their marketing strategies and the deposit rate (ii) different behaviour patterns of clients in different banks and (iii) the Bank is *the traditional bank* and therefore, would provide bias estimates for the *low-cost bank*.

In the equation (4.5) $c_{i,t}$ is the deposit rate and $V_{i,t}$ is the volume in savings accounts at time t in the bank i. Evidently, the development of volumes is not constant, but the growth in volumes changes based on the deposit rate at time t. The model for dynamics of savings accounts volumes presented in the equation (4.5) is able to reflect that volumes grow at a higher rate in a bank that offers higher rate, which we found to be true in the case of *the low-cost bank*s. One may argue that assuming that volumes grow at the deposit rate is not sufficient as we found that volumes grow at a substantially higher rate than is the recapitalization of volumes. This growth is due to reasons other than interest inflows, i.e. some clients deposit regularly a part of their income on savings accounts or they make one large initial transfer when setting up the account. We also neglect small changes in the balance. Savings accounts are by definition savings instruments, not payment instruments as current accounts. Clients therefore change balance on their savings accounts usually in three cases: when they set up the account, when they deliver excess income as savings to savings accounts and when they withdraw all balance. We neglect future deliveries into the accounts as well as withdrawals in our model. In other words, the model in the equation (4.5) assumes that in each bank, volumes will not decrease below its initial value due to no withdrawals, i.e. $V(0) \leq V(t)$ for $\forall t \epsilon (0, T)$. In a strict sense, the volumes we model may be seen as the core balance. A bank does not expect changes in this core balance during the estimation period and therefore it can reinvest the whole balance into different instruments. The assumption of the stable core balance is employed in banks' stress testing procedures and is therefore in line with professional practice. If we would possess data to estimate future inflows, these might be easily included into the model as expected cash flows at time t, i.e. in each time t a bank would reinvest these inflows. Outflows, on the other hand, would need to be a subject to a more comprehensive study of the liquidity risk of savings accounts. The model as defined in the equation (4.5) is sufficient for the interest rate risk management, but would not be sufficient for the liquidity risk management.

4.2.5 The Replicating Portfolio Model

The theory behind replicating portfolios is described in section 3.2.1. Here we focus on practice and the construction of our replicating (reinvestment) portfolio. Replicating portfolios are ideally constructed to replicate cash-flows from non-maturing liabilities in such a way that the replicating portfolio consists of instruments with known maturities, which cash-flows replicate cash-flows from non-maturing liabilities. Banks invest into these instruments under different weights in such a way that the margin is maximized or the least volatile. The duration of the replicating portfolio is then calculated as the weighted duration of these instruments, and the interest income from the replicating portfolio is used to cover interest expense and provides income to a bank. To ensure liquidity, banks usually divide volumes into core and volatile parts. The core part is reinvested into medium-term and long-term instruments. The volatile part represents amounts that change on savings accounts on a daily/monthly basis. The volatile part of savings account is invested into short-term instruments (usually from overnight tenors to 3M) that ideally mature in such a way that maturing tranches are able to cover daily withdrawals. Table 4.6 includes literature review for the replicating portfolio models.

Table 4.6: Literature review for NML replicating portfolio models

Author/s	Static/Dynamic	Notes
Maes and Timmermans (2005)	Static	The duration is found to differ substantially under different stress test.
Dewachter, et al. (2006)	Dynamic	The duration differs substantially for Sharpe ratio and standard deviation of the margin minimization as well as in the case of the optimization with holding period returns and yields. Authors note the minimization of the standard deviation provides results similar to valuation method.
Kalkbrener and Willing (2006)	Static	-
Frauendorfer and Schurle (2006)	Dynamic	Dynamic portfolio found to be more efficient.

Source: Author

The replicating portfolio estimation in banks is based on the optimization described, for example, in Maes and Timmermans (2005):

$$\begin{gathered} min\sigma_M \ or \ maxM, M = \left(II_{RP} - c_{i,t}\right) \\ s.t.: \ \sum_{i=1}^{n} II_i w_i = II_{RP}, \sum_{i=1}^{n} w_i = 1, w_i \geq 0, \forall i, V_{i,t,not\ invested} = 0 \end{gathered} \tag{4.6}$$

In the equation (4.6) we either minimize the standard deviation of the margin σ_M or maximize margin M. II_{RP} is the interest income from the replicating portfolio that equals to the sum of interest incomes of all individual investments and w_i is the weighth of each investment and as no short-selling is allowed, its value is always positive or zero. The last condition is that all volumes are perfectly replicated for all t, i.e. no money lays back.

To construct our portfolio, we defined the model for market rate in section 4.2.2, which provides the term structure of interest rates, the model for deposit rate in section 4.2.3 and the model for savings accounts volumes in section 4.2.4. These models jointly characterize the amount a bank can reinvest as well as the amount a bank pays to its clients in the form of the deposit rate expense. This is the common set-up in which Maes and Timmermans (2005), Dewachter, et al. (2006), Kalkbrener and Willing (2004) and Frauendorfer and Schurle (2006) construct their either dynamic or static replicating portfolios. The aim of the models in these studies is to estimate optimal maturity buckets in which a bank should reinvest savings deposits either by the minimization of the standard deviation of the margin or by the maximization of a margin by the Sharpe ratio as defined in the equation (4.6). Our analysis differs. We intend to investigate whether a similar investment strategy results in different outcomes for the capital in banks that use different risk management of savings accounts (differences in the risk management are driven by the competition, i.e. by the willingness of a bank to increase the deposit rate) under random simulations as well as under different scenarios for the market rate. Therefore, our aim is not to calculate savings accounts' duration and optimal reinvestment, but to derive a yield from given reinvestment strategy, i.e. under defined reinvestment weights. In this, our replicating portfolio can be viewed as simple reinvestment portfolio.

The reinvestment defined in our analysis represents an average strategy of banks in the Czech Republic (according to our market knowledge). In our model, each bank type reinvests savings accounts volumes of CZK 100 million in retail into the replicating portfolio under weights w_i (see Table 4.7 for scenarios and Table 4.8 for simulations) with the condition that $\sum_{i=1}^{n} w_i = 1$ and that no short selling is allowed. Those CZK 100 million are considered as a core balance. Banks usually reinvest the core of deposits into long-term instruments. However, as savings accounts are interest rate sensitive liabilities, we let banks in our analysis to reinvest a core balance also into short-term instruments to accounts for this sensitivity. For *the low-cost bank*, we define two types of portfolios: non-aggressive and aggressive. Aggressive portfolio shows that riskier investment of savings accounts results in positive net interest income even under a relatively high deposit rate, but at the cost of a risky position in high-yield instruments, such as consumer loans or mainly corporate bonds. We partially base our aggressive portfolio on the interview in Face to Face by Tinl

(2012), where Erich Čomor, the CEO at Air Bank, mentions the Air Bank's reinvestment strategy.

Table 4.7: Weights of different reinvestments in the replicating portfolio for scenarios

The traditional **and the** ***third type bank***	***The low-cost bank*** **non-aggressive portfolio**	***The low-cost bank*** **aggressive portfolio**
10% of deposits is invested into O/N rate. 10% of deposits is invested into 3M. 40% of deposits is invested into 10Y. 40% of deposits is distributed as loans and mortgages to clients: 1. 13.3% of deposits is invested into 1Y fixed rate consumer loans for CZK 30,000 with r = 20%. 2. 13.3% of deposits is invested into 5Y fixed rate consumer loans for CZK 100,000 with consumer loans' interest rate of r =15%. 3. 13.3% of deposits is invested into 20Y fixed rate (fixing for 5 years) mortgages for CZK 1,000,000 with 4% rate.	10% of deposits is invested into O/N rate. 10% of deposits is invested into 3M. 40% of deposits is invested into 10Y. 40% of deposits is distributed as loans and mortgages to clients: 1. 13.3% of deposits is invested into 1Y fixed rate consumer loans for CZK 30,000 with r = 15%. We let consumer loans' interest rate r in *the low-cost bank* being lower than in *the traditional bank* and *the third type bank* as we found that these are lower on average. 2. 13.3% of deposits is invested into 5Y fixed rate consumer loans for CZK 100,000 with r =10%. 3. 13.3% of deposits is invested into 20Y fixed rate mortgages (fixing for 5 years) for CZK 1,000,000 with 4% mortgage rate.	10% of deposits is invested into O/N rate. 10% of deposits is invested into 3M. 33% of deposits is invested into 10Y. 14% of deposits is distributed as loans and mortgages to clients: 1. 5% of deposits is invested into 1Y fixed rate consumer loans for CZK 30,000 with r = 15% 2. 5% of deposits is invested into 5Y fixed rate consumer loans for CZK 100,000 with r =10%. 3. 4% of deposits is invested into 20Y fixed rate mortgages (fixing for 5 years) for CZK 1,000,000 with 4% rate. 33% of deposits is invested into long-term (maturity higher than 5 years) foreign-owned company bonds that provide 10% annual yield.

Source: Author

All instruments in the replicating (reinvestment) portfolio are hold to maturity and rolled over when matured. The increasing balance on savings accounts is redistributed under these weights in each estimation step so that whole balance is always invested in each step. We always let each bank reinvest all increments in savings accounts' balance + interest income from the previous month investment before the interest expense paid to depositors as we include no withdrawals into the model. This simplification reflects the fact that whole balances + interest increments before the interest paid to depositors are assumed to remain in a bank that later reinvests this money. A rational bank reinvests all the money, i.e. not paid interest expense liability is in fact asset bearing interest.

Consumer loans and mortgages pay interest monthly and interest + principal returns (calculated as annuity) are rolled over as new consumer loans and mortgages. The inclusion of loans and mortgages is also an important difference between our and classical replicating portfolio approach. By adding these, we are able to derive the more realistic revenue of a bank. Money market instruments pay interest + par value at maturity and 10Y government and long-term company bonds pay yields annually. We derive monthly steps, i.e. in each month a bank receives maturing investments, repayments + interest from loans and mortgages and yields from bonds and rolls them over. Consumer loans' and mortgages' interest rates as defined in Table 4.7 are initial values of those. As soon as market rates start to increase, banks will increase consumer loans' and mortgages' interest rates on newly provided consumer loans and mortgages as well. To account for this, we let consumer loans' and mortgages' interest rates to grow at the growth of the market rate.[31] Loans and mortgages are risky assets as there is always some percentage of defaults. We include defaults into our analysis and we define defaults to be 2% in *the third type bank* and *the traditional bank* and 5% in *the low-cost bank*s.[32] In simulations we cease the inclusion of consumer loans and aggressive strategy and we let each type of a bank to reinvest solely on the money and bond market.

Table 4.8: Weights of different reinvestment in the replicating portfolio for simulations

Maturity	Weights (equal for all types of banks)
O/N (overnight)	13.33%
3M	13.33%
6M	13.33%
1Y	13.33%
5Y	23.33%
10Y	23.33%

Source: Author. The selected maturities represent average horizon over which banks usually reinvest their funds.

[31] Dynamics of consumer loans' interest rates are as follows: $\Delta r_{i,t} = r_{i,t-1} + m_t - m_{t-1}$, $\mathrm{i} = The\ traditional\ bank,$ the $low - cost\ bank$ and $the\ third\ type\ bank,\ t = 1 \dots, T,\ r_{i,t}$ is the consumer loans' interest rates.

[32] We let the *low-cost bank* to have higher defaults as we have found that, for example, Equa bank reported the share of receivables in the expectation of default in all receivables to be 22.98% as of 30 September 2012 and 27.05% as of 31 December 2012.

As mentioned above, classical replicating portfolios replicate cash flows from demand deposits to optimize bank's margin. Usually, the linear replication is applied in the case of the static approach (Strnad, 2009). A linearly maturing replicating portfolio (for example, the cyclical reinvestment into 10Y means that in each year, one tenth of the portfolio is maturing and rolled over) must be build up gradually to ensure that in each time t, a bank receives and reinvests constant part of the portfolio. We employ different approach. As our aim is to derive the potential net interest income from the reinvestment of the balance of CZK 100 million of savings accounts, we assume that a bank reinvests this balance at once (no money lays back). Such approach reflects the fact that savings accounts represent a large part of new, not yet invested deposits.

4.2.5.1 Interest Income from Different Positions, Interest Expense and the NII from the Replicating Portfolio and its Impact on Capital

Each reinvestment position in the portfolio generates income monthly. Monthly incomes from different positions are derived in detail in Appendix 8.3 and the reader can refer to them there. The deposit rate expense[33] is also paid monthly. Hence, the net monthly income is calculated as the monthly income from all reinvestment positions minus the deposit rate expense. All monthly net incomes are than summed on a yearly basis. The cumulative net interest income is calculated as the sum of all net incomes in given years. The same procedure of the calculation is employed in all types of banks. The cumulative net interest income after T periods directly influences bank's capital. When a bank has positive cumulative net interest income, this income is simply added to the capital at the end of the scenario and it exactly increases by the net interest income. The initial value of capital is set to CZK 10 million. A bank can have monthly interest income negative, if the monthly interest income from all position is lower than the monthly interest expense. If a majority of monthly incomes is negative, the total yearly income is also negative, and obviously the cumulative net interest income is negative as well. In such case, we assume that the net loss is paid from the bank's capital at the end of the scenario or simulation at the period T. This means that a net loss in our model does not influence the bank's reinvestment policy; it only decreases its capital ultimately.

[33] When calculating the interest paid to depositors, we use $\left(\sqrt[1/12]{1+c_{i,t}}\right)\mathrm{V}_{\mathrm{i,t-1}}$ → the interest expense equals recapitalization.

Additionally, this simplification ensures that banks with negative monthly interest income will not have negative investments.

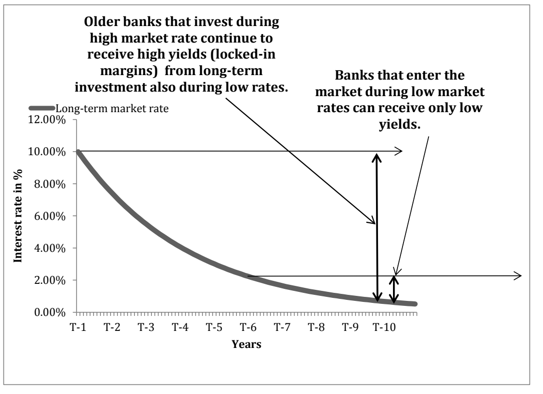
5 Interest Rate Risk of Savings Accounts Empirically - the Impact of Low Market Rates, Simulations and Scenarios

In this chapter we first analyze the low market rates period we observe since 2012 as it poses several important implications for our analysis of savings accounts. Second, we address simulations and scenarios for the interest rate risk of savings accounts.

5.1 Low Market Rates Period and its Impact

Figure 5.1 illustrates that the banks that enter the market during decreasing market rates (as denoted by time T) have lower yields from replicating portfolios than the other banks that were able to construct their replicating portfolios during the period of high market rates (especially in time T-9). This implies that a bank that enters the market during extremely low market rates can reinvest deposits either into very low yields in the short-term, or it can lock in long-term instruments that also bear a low yield. The pending low wholesale market rates imply that new banks de facto cannot achieve high margins from the reinvestment of demand deposits and should therefore provide lower deposit rates (ideally under the long-term market rates level). Older banks, on the contrary, have lower income than during high market rates but a stabilized and positive income also during low market rates as they continue to receive high yields from long-term investment into government bonds and currency swaps. The margin in older banks is smoothed and high yields from the high market rates period help to overcome decreasing income from the low yield period (build up replicating portfolio yields stable margin).

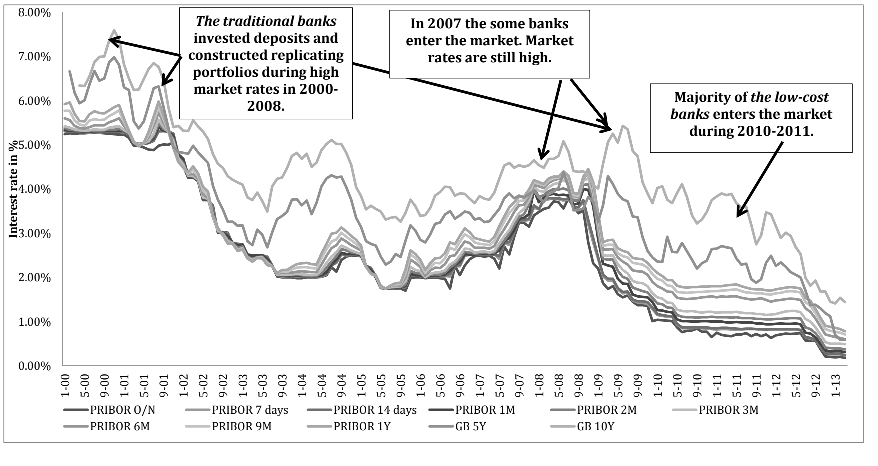
Figure 5.1: Theoretical bank's yield under low and high market rates



Source: Author

Figure 5.2 shows that market rates are since October 2012 at their historically minimum levels and have been rapidly decreasing since 2011. The figure also shows that new banks that entered the market after 2007, and mainly after 2010, are having a relatively worse position than banks that invested a majority of their funds in the earlier period at higher yields (locked-in higher yields), as similarly described theoretically above. Many new so called *low-cost bank*s entered the market during 2007 - 2011. This implies that the yield from the reinvestment in *the low-cost bank*s must be lower than the yield from the reinvestment in *the traditional bank*s that invested their portfolios during 2000 - 2007.

Figure 5.2: Selected market rates in the Czech Republic from 1 January 2000 to 31 March 2013



Source: Author using the data provided by CNB

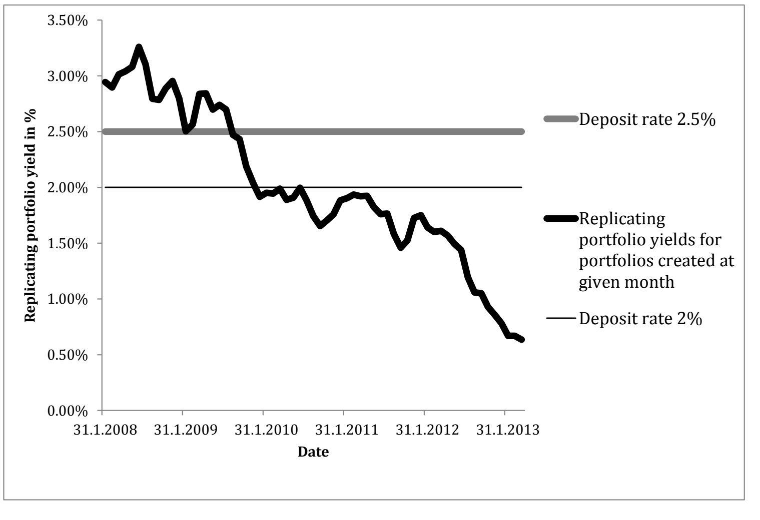
To show that high deposit rates offered on savings accounts in *the low-cost bank*s are not in accordance with the development of the market, we construct a fictional replicating portfolio's yield development in banks that entered the market after 2007. We assume that a bank starts to construct the replicating portfolio at the beginning of a new year after its entrance on the market as by this time it should already have enough deposits to reinvest them. To derive potential replicating portfolio of *the low-cost bank*s since 2008 we assume that all *the low-cost bank*s invested savings accounts only into several market instruments with weights as in Table 4.8. The data for short-term and long-term maturities were downloaded from the ARAD time series database and consists of monthly average annual yields from 31 January 2008 to 31 March 2013. Each bank has an option to invest balances on savings accounts into these maturities monthly, i.e. we derive a potential yield from the replicating portfolio that is constructed each month since January 2008 to March 2013. Instruments with maturities lower than one year, i.e. O/N, PRIBOR3M and PRIBOR6M, are discounted by 30/360. We show only the net interest income from the reinvestment on the market as banks usually reinvest a large part of funds on the market. For the derivation of the sustainable deposit rate, the assumption of the reinvestment only on the market is in accordance with practice as banks derive sustainable deposit rates from the money market. For simplicity we assume that the balance that is invested into the replicating portfolio is always CZK 1 in each month. In reality, a bank would reinvest each month different balances, based on the initial amount reinvested, maturing instruments, withdrawals and new deposits.

We derive a static replicating portfolio yield using the equation (4.6) and assume that all instruments are held to maturity or reinvested (reinvestment included in CZK 1). Under decreasing market rates this means that maturing instruments are always reinvested at lower yields. We also assume only positive weights, i.e. we do not allow for short selling, and the sum of weights is 1, which is also one of the conditions the replicating portfolio must satisfy.

Figure 5.3 shows sustainable yields, which equal sustainable or a break-even deposit rate, new banks could gain from the reinvestment on the market since 2008. Evidently, any deposit rate higher than 2% would result in the net interest rate loss after 2010 given a bank would invest only on the market. An important note is that the many new banks (Air Bank, Equa bank, Axa Bank, Zuno) entered the market after 2009 and offered deposit rates higher than 2%

during August 2012 to December 2012. Therefore, a majority of new banks in the Czech Republic offered deposit rates that were not in accordance with the market. During January 2012 - March 2013, all banks decreased the deposit rate; see Figure 2.5, which in turn might improve their numbers. However, decreased deposit rates are still significantly above the maximal potential yield derived in Figure 5.3. This implies that the net interest income from savings accounts must be negative in banks that are new and offer high deposit rate bearing savings accounts, i.e. in *the low-cost bank*s. We argue that holding deposit rates at the expense of negative interest income is a direct consequence of interest rate and reputational risk of savings.

Figure 5.3: The development of maximum replicating portfolios yields banks that entered the market after 2007 from 1 January 2008 to 31 March 2013

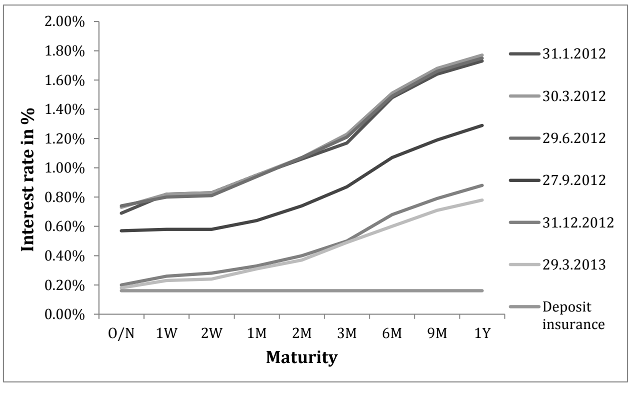


Source: Author's own calculation

For a bank dependent on savings accounts, the negative margin from savings accounts must imply negative profit from the whole business. To support this conclusion, we analyzed annual and quarterly reports of Air Bank and Equa bank. We find that Air Bank reports negative net interest income as of 31 March 2012 and 31 June 2012. As of 31 September 2012, the net interest income turned positive, but still very low. As far as the net profit in Air Bank is considered, we find that Air Bank generates negative profit since 31 December 2011 to 31 December 2012. Equa bank also reports negative profit since 31 December 2011 to 31 December 2012. However, its interest income is always higher than the interest expense. We find evidence that a high deposit rate bearing savings accounts and the dependence on them results in negative profits. However, these negative profits may also stem from other sources: (i) costly business buildup period and (ii) zero fee policy. Nevertheless, the business model based on the acquisition of liquidity through risky instruments such as savings accounts and at the cost of negative profit is at least questionable.

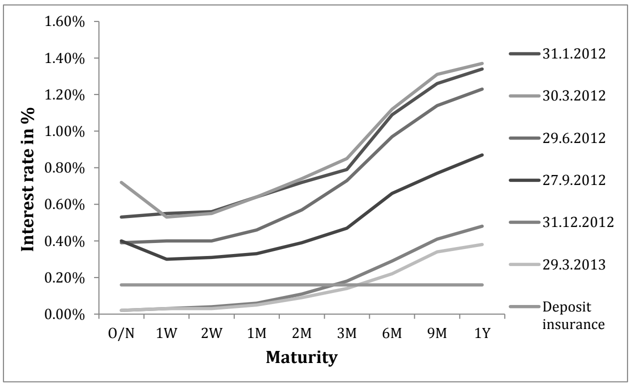
To further point out the effect of low market rates, we include Figure 5.4 showing short-term PRIBOR rates during 31 January 2012 to 29 March 2013 and Figure 5.5 showing PRIBID rates during 31 January 2012 to 29 March 2013. Evidently, since the end of 2012, the shortest PRIBID rates provided the yield even lower than is the obligatory insurance (0.16% on a yearly basis, paid quarterly at the rate of 0.04%). This means that any bank is practically in a net loss when depositing short-term funding in another bank. Such rapid decrease in the short part of the yield curve will definitely negatively influence the net interest income in all banks during 2013 at least. When compared to these low rates, savings accounts' deposit rates in Figure 2.5 are truly striking.

Figure 5.4: The decrease in PRIBOR rates since January 2012



Source: Author and CNB

Figure 5.5: The decrease in PRIBID rates since January 2012



Source: Author and CNB

5.2 Simulations and Scenarios for the Future Development in Banks' Margins

In section 3 we have identified five risks of savings accounts that should be hedged by banks' risk managers. Moreover, we provide empirical evidence that current savings accounts' deposit rates are too high in section 5.1. High deposit rates are a direct consequence of competition and aggressive acquisition of clients. We highlight that banks that have only a small part of liabilities in savings accounts can balance low or negative margins from savings accounts during low market rates by other high and stable margin bearing products as current accounts or long-term term deposits. However, in savings accounts dependent banks, the net loss from savings accounts is neither balanced by income from fees or other demand deposits and owing to this, these banks generate negative profit.

We observe three challenges of the risk management of savings accounts in the Czech Republic: (i) insufficient hedging of all risks, (ii) competition and aggressive acquisition of new clients resulting in unsustainably high deposit rates and (iii) the lack of adequate regulation. Given these, we see it relevant to estimate the impact of savings accounts on a bank's capital. We construct a model that estimates the impact of the competition and high deposit rates on banks' capital under (i) simulations and (ii) 6 market rate scenarios. Our aim is to show that savings accounts are risky financial instruments especially in banks depending on funding from savings accounts. Such banks might face capital shortage as a result of unsustainably high deposit rates and related low profitability. We argue that as soon as market rates start to increase, banks (mainly *the low-cost* ones) will either bid for liquidity or try to retain their clients through offering high deposit rate bearing savings accounts. As there is no explicit cap on deposit rates, banks can freely increase the rate. Based on our analysis of the market, we propose to test following hypotheses:

1. **Savings accounts are a source of the interest rate risk for all banks in the Czech Republic** and mainly for savings accounts dependent banks, i.e. *the low-cost bank*. This interest rate risk stems from four main channels: (i) competition and acquisition presented by high deposit rates combined with (ii) the impossibility of high interest income during low market rates, (iii) the lack of other sources of funding and (iv) increasing market rates pushing deposit rates to increase combined with a high share of long-term funding with low annual yields from low market rates.
2. **Savings accounts are a potential source of instability (systemic risk).**

We supported the parts (i), (ii) and (iii) of the hypothesis one in the case of *the low-cost banks* in section 5.1 and thorough our thesis and market analysis. We stress that the strategy of aggressive acquisition of clients through offering a high deposit rate would be sustainable in the short run under the assumption of compensation from the powerful market position in the long run. However, in section 2.3 we find that many savings accounts clients are interest rate sensitive ones. This implies continuing competitive environment among banks, which in turn results in continuously high deposit rates.

5.2.1 Simulations

Simulations continue with the analysis presented in Figure 5.3 into the unknown future and show the development of the feasibility of the reinvestment of savings accounts on the market under random development of market rates. The market rate is simulated by drawing random error terms (Monte Carlo Simulation drawing random terms from standard normal distribution.). The starting value for each market rate is the 2W repo rate value as of 31 March 2013 (0.05%). We start to simulate at low market rates to be in accordance with the market development. We want to show possible development of Czech banks' margins from savings accounts in next two and five years. We run 1000 simulations for 24 months and 1000 simulations for 60 months. Yields on instruments are derived from (4.3). Each bank reinvests CZK 100 million as a core balance, i.e. no outflows and inflows as defined in section 4.2.4. The deposit rates are simulated as defined in section 4.2.4.1. The code for simulations is written in Wolfram Mathematica and available on request.

Table 5.1 summarizes average result across the 1000 simulations. We find that for any type of analyzed bank, it is not feasible to reinvest savings accounts only on the market as the net interest income is negative for 24 months as well as for 60 months in all banks. This indicates that the reinvestment of savings accounts that bear a high deposit rate would be feasible only if banks would invest in other investment, such as consumer loans or mortgages. However, these instruments are less liquid and secure than the reinvestment on the market. This exposes banks to a higher liquidity and credit risk, but provides a higher interest income. The result we obtained is in line with conclusion we derived in Figure 5.3, where we find that the reinvestment of savings accounts by *the low-cost bank*s on the market could provide yields only lower than many deposit rates offered in those banks. However, in Table 5.1 we find that also *the traditional* and *the third type bank*s would not be able to generate positive interest income from the reinvestment of savings accounts on the market, assuming that this reinvestment starts at low market yields, i.e. as of the end of 2012 and the beginning of 2013. On the other hand, these banks have a higher share of other products (current accounts), which would balance their low/negative net interest income from savings accounts. The result of simulations shows that savings accounts are risky liabilities for all banks. We also find that the reinvestment of the core of savings accounts that starts during low market rates is not able to provide positive net interest income for a long period. The duration[34] of the portfolio in Table 4.8 is 3.7 years. Therefore, for increasing market rates, it will take on average 3.7 years before any type of bank will get rid of low yields.

Table 5.1: Average cumulative net interest income from the reinvestment of savings accounts after 24 and 60 months

CZK thousands	*The traditional bank*	*The low-cost bank*	*The third type bank*
24 months	-1,295.7	-4,332.1	-2,808.2
60 months	-1,701.5	-13,479.5	-6,944.28

Source: Author's own calculations. The average income is calculated as an average income from the reinvestment of savings accounts under 1000 random simulations of market rate.

[34] Calculated as weighted duration of all instruments.

5.2.2 Scenarios - Stress Testing

We find that the reinvestment on the market is not sufficient and that consumer loans and mortgages are a necessary reinvestment to ensure a feasible margin from the reinvestment of savings accounts. A scenario analysis enables us to include consumer loans and mortgages into our analysis.[35] Our scenario analysis requires the market rate to reach some values as our aim is to test the impact of increasing market rates. We explicitly assume that we know how the market rate will develop and we derive conclusions from this expected development. We let the market rate develop in steps from the initial value of 0.05%, each step equal to defined amount of months,[36] in which the central bank always sets the rate. Table 5.2 lists all scenarios. Banks then adjust the deposit rates on their savings accounts based on this market rate and Table 4.4. In Appendix 8.4 we include charts for the development of market rates and deposit rates for all scenarios and types of banks. As simple as our scenarios might look, it is a common practice of stress testing in banks to let the yield curve to change in parallel. In our set up, we let the market rate to change, not a yield curve, and derive yields from this market rate. In our approach, the yield curve changes are non-parallel.

Table 5.2: Scenarios for the market rate

Scenarios	Final value of the market rate	Duration to the final value in months
Scenario 1	0.05%	24
Scenario 4	0.05%	60
Scenario 2	2%	24
Scenario 5	2%	60
Scenario 3	5%	24
Scenario 6	5%	60

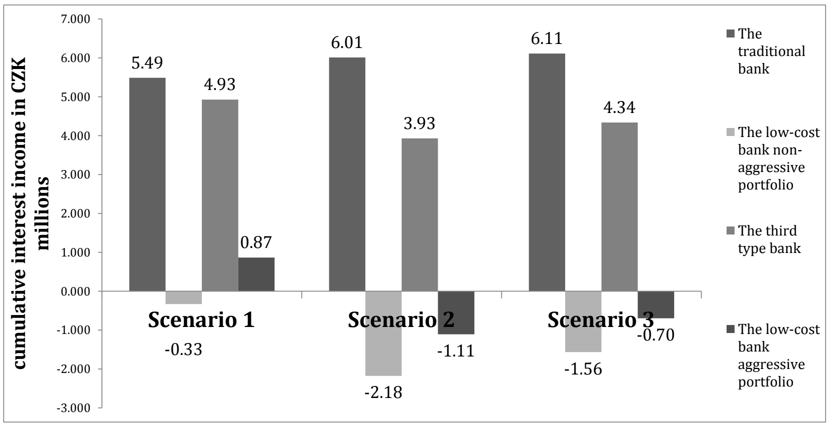
Source: Author

[35] The code for simulations could not include consumer loans and mortgages due to the fact that for example for 5Y consumer loans, there would have to be AR(60) lag included in the code, which was not operationally possible. As scenario analysis is done in Microsoft Excel and for a limited number of scenarios, we can include mortgages and loans relatively easily.

[36] Usually each two or three months for two-year scenarios and each seven or five months for five-year scenarios

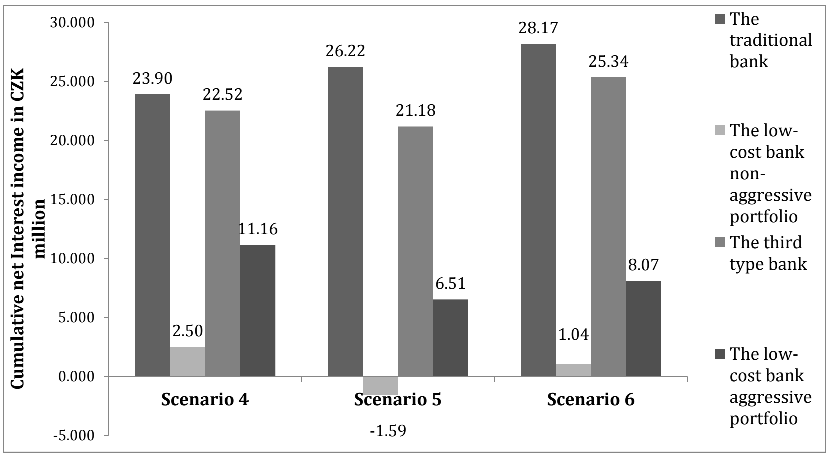
Figure 5.6 and Figure 5.7 show the cumulative net interest income all types of banks were able to generate from the reinvestment of savings accounts into the portfolio as defined in Table 4.7 for Scenarios 1-3 and Scenarios 4-6 respectively. Both *the traditional bank* and *the third type* generate positive net interest income from savings accounts in all scenarios. This shows, as we assumed, that the reinvestment of savings accounts that starts during low market rates can provide feasible income under two conditions: (i) a bank has to reinvest a substantial part of liabilities into riskier instruments, such as consumer loans and mortgages, and (ii) a bank must offer sustainable deposit rate that is in accordance with the market.

Figure 5.6: The cumulative net interest income from the reinvestment of savings accounts for Scenarios 1-3



Source: Author's own calculations

Figure 5.7: The cumulative net interest income from the reinvestment of savings accounts for Scenarios 4-6

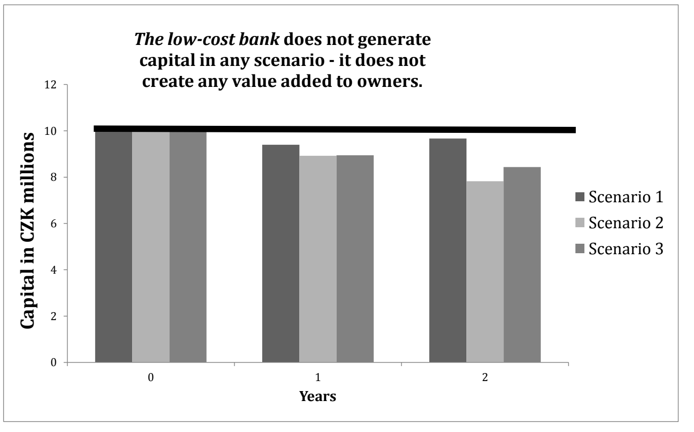


Source: Author's own calculations

Focusing on *the low-cost bank*s, we find that they are able to generate positive cumulative net interest income that would cover a high deposit rate only for the aggressive reinvestment strategy under Scenarios 1, 4, 5, and 6, while Scenarios 1, 2, 3, and 5 for the conservative portfolio generate negative interest rate income in the observed periods. As *the low-cost bank*s generate negative interest income, we derive the impact of this negative net interest income from savings accounts on the capital in those banks. We assume that the initial value of the capital is CZK 10 million, which corresponds to a 24% capital adequacy[37] in the case of a non-aggressive portfolio and 19% capital adequacy in the case of aggressive portfolio. For simplicity, we exclude all other costs and revenues, such as taxes, obligatory deposit insurance or charged fees. We also exclude the possibility that this loss might be covered up by the other reinvestment of future new deposits at higher rates. These future inflows are unsure and thus we employ conservative approach and calculate only with the initial reinvestment of CZK 100 million. By doings so, we obtain the direct impact of the reinvestment of savings accounts on the capital in *the low-cost bank*s. Figure 5.8 shows the impact on the capital of the non-aggressive strategy for two-year scenarios (Scenarios 1, 2 and 3) as the net loss is the highest in those scenarios and the rest of figures describing the impact on capital can be found in Appendix 8.5. The figure shows that that capital decreases in all scenarios. Particularly, it decreases by 21% in Scenario 2 and by 15% in Scenario 3. Therefore, we find that a quick increase in the market rate to 5% in Scenario 3 leads to slightly lower loss than an increase to 2% in Scenario 2. This is a result of increasing consumer loans' interest rates and yields on bonds as in Scenario 3 these increase more than the deposit rate. We also find that stagnation in market rates would lead to the lowest loss, which indicates that increasing market rates are a crucial factor. We conclude that under increasing market rates, *the low-cost bank*s might lose up to 21% of their capital within two years.

[37] CAR (capital adequacy) = capital/RWA, where RWA are risk weighted assets. We use common risk weights proposed by BIS. The current regulatory requirement is that CAR should not be lower than 10%.

Figure 5.8: The impact on capital for a non-aggressive strategy and Scenarios 1-3



Source: Author

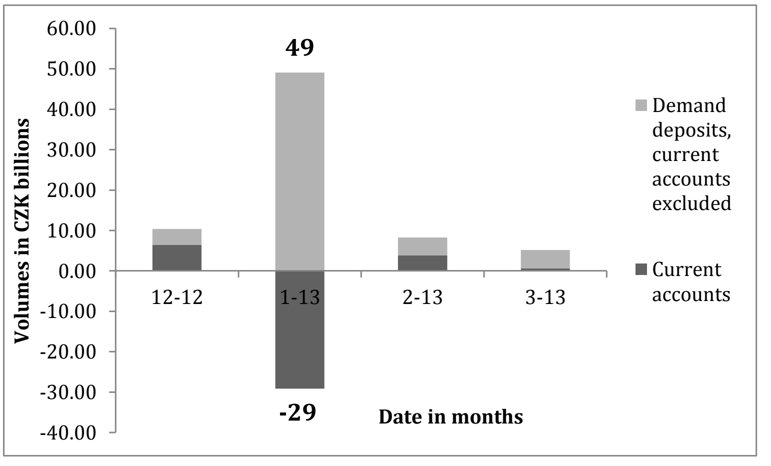
We find that only aggressive strategy is sufficient to generate positive income from the reinvestment of a high deposit rate bearing savings accounts when market rates start to increase. Under prevailing low market rates, the stagnation in deposit rates is not as detrimental and capital losses are minimal or even none, as Scenario 1 and 4 show. However, increasing market rates are a crucial factor. We raise the question whether an aggressive strategy is consistent with sound risk management of savings accounts, however. We argue that savings accounts are risky instruments for all banks as only either aggressive strategy or riskier reinvestment (loans) can provide positive interest income that would cover the high deposit rate payment. We do not reject hypothesis one.

We also see the possibility that risky business based on the acquisition of liquidity through a high deposit rate bearing savings accounts may not be in accordance with the law in the long term. We reference to The Article 12 from Act No. 21/1992 Coll. of 20 December 1991, on banks that states: "*A bank or a branch of a bank from a non-Member State* ***shall carry on its activities with prudence*** *and, in particular, pursue its business in a manner which is not detrimental to the interest of its depositors in respect of the recoverability of their deposits and* ***which does not endanger the bank's safety and soundness***" We doubt that a high interest bearing savings accounts can provide any long term counter value for a bank in the sector where banks compete for liquidity and active clients. We argue that business that in fact destroys the value in the long term is not prudent. The soundness of banks that offer unsustainable deposit rates is also a question. Banks should not provide a high deposit rate bearing savings accounts at the cost of their capital.

5.2.3 Systemic Risk

In this section, we test hypothesis two. Even though the empirical analysis is dedicated to the interest rate risk of savings accounts, the model we developed enables us to assess systemic risk of savings accounts as systemic risk stems from the interest rate risk of savings accounts, but not on an individual/micro bank level, but on the macro level. We observe significant increases in savings accounts, which, given their interest rate risk, increases systemic risk of savings accounts. Figure 5.9 depicts the monthly changes on aggregate current accounts and aggregate Demand deposits, current accounts excluded in retail during 31 December 2012 - 31 March 2013. The sharp decrease in current accounts in January 2013 and subsequent increase in the category Demand deposits, current accounts excluded results from the change in the banks' reporting to CNB and illustrates the transfer of savings accounts from current accounts to Savings demand deposits (a category under Demand deposits, current accounts excluded). This transfer, according to CNB, amounted CZK 39 billion in the case of retail deposits (note that the decrease on current accounts of CZK 29 billion in Figure 5.9 includes inflows into current accounts as well, which is why it does not equal CZK 39 billion outflow from reclassification). Additionally, current accounts grow less since the increased attractiveness of savings accounts. This indicates that money flows from current accounts to savings accounts. Savings accounts represent a majority of deposits in Demand deposits; current accounts excluded and we derive that this category increased by CZK 49 billion as of 31 January 2013, which is more than CZK 39 billion reclassification from current accounts. This indicates that money flows to savings accounts not only from current accounts. Furthermore, we observe more trends that explain an increase in aggregate savings accounts. First, aggregate term deposits in retail have a negative or very low growth steadily since 2010. Second, the clients' behaviour patterns are changing. Active clients with low balances on current accounts and higher savings on savings accounts are replacing older and passive clients. Third, the decreasing attractiveness of building savings will result in the transfer of deposits on building savings to other savings instruments and given the attractiveness of savings accounts, to savings accounts in many cases. This all suggests that, should savings accounts' deposit rates remain attractive; aggregate savings accounts will grow in the future.

Figure 5.9: Dynamics of current accounts and other demand deposits during 31 December 2012 - 31 March 2013



Source: Author and CNB

To be conservative, we approximate aggregate savings accounts volumes of CZK 250 billion as of 31 March 2013 and we expect that after five years, there will be CZK 500 billion. To end up with CZK 500 billion, we let volumes to increase by CZK 4.3 billion each month during five years, including the recapitalization of previous period volumes. To obtain the aggregate cumulative net interest income from the reinvestment of savings accounts, we define *the median bank* simply as a bank that adjusts the deposit rate and reinvests as the average bank of all our types of banks, see Table 8.5 in Appendix 8.6. *The median bank* reinvests aggregate savings deposits under the same weights as *the traditional* and *the third type bank* and the non-aggressive portfolio of *the low-cost bank*, but *the median bank* provides average interest rate on consumer loans across all types of banks. Defaults in *the median bank* are set at 3%. The recapitalization of the core balance of CZK 250 billion and maturing instruments are reinvested as in Table 8.5. On the contrary, further inflows, their recapitalizations and roll overs are reinvested only into O/N and 3M maturities to account for strong liquidity pressures in the competitive environment, i.e. the need to hold more liquid assets.

We attain our five-year scenarios for the market rate, i.e. Scenario 4, 5 and 6. We find that for all five year scenarios, the sector would cumulatively generate positive interest income from CZK 23.59 billion to CZK 45.97 billion. This leads us to reject the hypothesis two. However, this positive interest income stems from: (i) an assumption that a large part of savings accounts deposits will be placed in large banks that offer low deposit rate (i.e. *the median bank* reinvests as an average bank) and (ii) large inflows of deposits can be invested at higher yields as market rates increase, what creates a cushion against the locked-in yield from low market rates.

From our analysis of the market, we know that savings accounts' deposits increase significantly in *the low-cost bank*s. We address this in our analysis of systemic risk as well and we find that should the majority of savings accounts be placed in *the low-cost bank*s, a sector would definitely generate negative interest income spanning CZK -3.56 billion to CZK -15.14 billion in Scenarios 4 and 5. In the case of Scenario 6, that assumes an increase to 5% within five years, even the sector where *the low-cost bank*s represent a major market player with savings accounts, would generate positive income. This is, as mentioned already, due to quick increase in market rates that enables to compensate low yields from low market rates rapidly. However, for moderately increasing market rates, as for example as in Scenario 2 and 5, the reinvestment yields are not as high and cannot compensate for a high deposit rate.

We conclude that even though we were not able to find the proof of systemic risk of savings accounts within our model for the systemic risk of savings accounts, this does not mean that systemic risk is not present. We see one main flaw of our model for systemic risk. The precise estimation of systemic risk of savings accounts would require the knowledge of the distribution of savings accounts deposits among *the traditional* and *the low-cost bank*s and the projection of this share.

5.3 Summary for the Empirical Analysis

Concerning our hypotheses, we do not reject hypothesis one, savings accounts are indeed risky liabilities for all banks and mainly for all banks as simulations showed. Hypothesis two is rejected, but not strongly and only because we do not possess the precise share of savings accounts among different banks in the Czech Republic. Savings accounts are risky liabilities and their interest rate risk hedging requires sustainable deposit rates as well as a higher income-bearing reinvestment. We provide evidence that many high deposit rates offered on savings accounts have not been sustainable since at least half of 2012. We find that in order to sustain high deposit rates during a period of increasing market rates (stress testing), banks will have to either opt for risky reinvestments or to increase its capital to cover the net interest rate loss from the reinvestment of savings accounts that was made during low market rates.

We argue that banks highly dependent on savings accounts are more exposed to all savings accounts risks because (i) they will probably have to offer a high deposit rate to retain depositors and (ii) they solely depend on the net interest income from savings accounts because of their common zero fee policies and the lack of other sources of funding. This is closely connected to the systemic risk of savings accounts as a higher share of aggregate savings accounts in *the low-cost bank*s will increase the systemic risk of savings accounts. We include Table 5.3 that relates our results to other authors.

Table 5.3: Connections between our analysis and other studies

Author/s	Result	Our results
Maes and Timmermans (2005)	Savings deposits raise stability issues in Belgium due to different risk management approaches in different banks as well as due to difficult risk mitigation stemming from embedded options.	Savings accounts are a source of the interest rate risk for Czech banks.
Kalkbrener and Willing (2006)	The deposit rate process should be derived from the market, i.e. based on the market analysis and banks' behaviour.	We carefully analyze the market and construct our deposit rate model based on the market analysis.
O'Brien (2000)	Reliability of the model depends on the deposit rate process.	We find that different deposit rate adjustment strategies lead to substantially different exposure to the interest rate risk. This reflects the need to define the deposit rate model correctly for each type of a bank. However, the need to unify models for regulatory purposes stands against this.
Frauendorfer and Schurle (2006)	Different time samples can be used to define models for market rate, deposit rate and volumes. Market rates are usually the longest samples.	Models in our analysis do not have unified time length.

Source: Author

We see the main problem in the high competitive rivalry. We assume that stricter regulation, for example, variable caps on deposit rates (in the form that a deposit rate should be derived from market rates), limits on balances that can be deposited by one person in a bank or longer notice periods on withdrawals that exceed a certain amount, would decrease the risk of savings accounts in any high-bidding banks as these would not be able to increase deposit rate above feasible values. Stricter regulation would also discourage other banks that do not yet offer "attractive" savings accounts. Another possibility is to focus on the moral hazard behind savings accounts. Clients deposit their savings on a high deposit rate bearing savings accounts in risky banks without any constraints as all deposits are, by law, insured. Should savings accounts be excluded from obligatory insurance scheme, many risk-averse clients would rather place their funds in sounder banks. Last but not least, the regulator should be able to assess a degree to which individual banks are exposed to savings accounts' risks. Maes and Timmermans (2005) point out the need of unified models used for modeling of savings accounts. A unified approach would enable the regulator to compare risk management of savings accounts in different banks, and to take actions if the risk management is not sound.

5.4 Further Research Opportunities

There are numerous further research opportunities. This thesis focuses on the interest rate risk management of savings accounts in the Czech Republic using the modified static replicating portfolio approach. However, a dynamic replication accounting for changes in the reinvestment strategies under different market rates is an interesting topic for a future research. Another possibility is to employ classical replicating portfolio approach and by the optimization exercise, to derive optimal reinvestment of savings accounts on the market. The analysis can also be extended by assessing risks of savings accounts in more countries, for example in the CEE region. This would enable cross-country comparison.

Apart from the interest rate risk and the systemic risk of savings accounts, further research should also focus on other risks. For example, liquidity risk and potential portfolio losses stemming from it are a center of regulator's attention these days and should be addressed accordingly by future research. Reputational risk can also be tested by assuming the crisis of the name and its subsequent impacts on a bank's deposits.

Last but not least, available data is an issue. For the Czech Republic, individual bank's data samples are either not available or are too short, which imposes limitations on both the deposit rate model and the dynamics of volumes model. We see the need of aggregate data, which as we mentioned above, would enable us to assess systemic risk of savings accounts properly. This might be a topic for consultations with CNB.

6 Conclusion

Savings accounts are risky liabilities with a legal duration of one day, characterized by two embedded options that make the risk management of savings accounts challenging. These options are the client's right to withdraw deposits on notice and the bank's right to change the deposit rate whenever it wishes. We identify that savings accounts are an important source of the interest rate risk and we focus on this type of risk. We employ the replicating portfolio approach as it is a widely used method to manage the interest rate risk of savings accounts enabling banks to estimate the duration as well as to derive the optimal reinvestment.

This thesis develops both theoretical and empirical analysis of savings accounts in the Czech Republic during the period of 1 January 2002 - 31 March 2013. It contributes to the analysis of non-maturing liabilities and their risks in Europe. We show that the Czech market for savings accounts has developed dynamically. As a result of the entrance of new banks, competitive pressures increased, which resulted in unsustainably high deposit rates in these banks. We show that high deposit rates offered on several savings accounts have not been consistent with the development of market rates, mainly since 2012.

We investigate more closely the interest rate risk of savings accounts using the static replicating portfolio approach and test the hypothesis that savings accounts are a source of the interest rate risk for Czech banks. We do not reject this hypothesis. From our analysis of the interest rate risk of savings accounts, we derive important conclusions: (i) savings accounts are a source of the interest rate risk for all banks in the Czech Republic, (ii) current low wholesale market rates imply the unsustainability of high deposit rates that are offered by several new banks in the Czech Republic, (iii) relatively high deposit rates are a consequence of competition and liquidity bidding, (iv) the risk profile of several new banks is risky due to their dependence on savings accounts, (v) savings accounts dependent banks may face capital losses when market rates start to increase, and finally (vi) savings accounts should be regulated to disable banks to acquire liquidity through a high deposit rate bearing savings accounts. We also test the hypothesis that savings accounts are a source of systemic risk that stems from the interest rate risk. We reject the hypothesis of systemic risk. Nevertheless, we argue that the systemic risk of savings accounts will probably increase in the future, even though the current evidence of systemic risk is not verifiable.

Our analysis assumes strong competitive pressures among banks resulting in a tendency to overshoot a deposit rate during increasing market rates. We stress that this is contingent on the fact that banks will continue to compete for liquidity when market rates start to increase. In the case of further prevailing decreases in deposit rates, either because prevailing low market rates or because the decrease in the competition (i.e., banks have already attracted enough funds), the interest rate risk of savings accounts will, based on our analysis, decrease.

Apart from the interest rate risk and systemic risk, we identified three more savings accounts risks: liquidity risk, reputational risk, and model risk. The empirical analysis of those risks and the calibration of more complex market rate, deposit rate and dynamics of volumes models were beyond the scope of this thesis and remain an interesting topic for a future studies. We aim to carry on with our research of savings accounts in the Czech Republic, focusing on the trends in dynamics of savings accounts during 2013 and modeling of other risks of savings accounts.

7 Bibliography

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Other resources:

Data from the anonymous bank located in the Czech Republic:

- savings accounts' volumes and the deposit rate offered on those savings accounts
- CZK daily swap rates from 1. 7. 2007 to 31. 12. 2011

8 Appendix

8.1 Deposit Rates

Table 8.1: Correlation between the deposit rate in the Bank, the 2W repo rate and selected short-term and long-term market rates for the monthly values from July 2007 to December 2011

The deposit rate in the Bank	2W repo rate	PRIBOR1D	PRIBOR1W	PRIBOR2W	
1.0000	**0.7741**	0.8069	0.8206	0.8238	The deposit rate in the Bank
	1.0000	0.9956	0.9949	0.9938	2W repo rate
		1.0000	0.9971	0.9961	PRIBOR1D
			1.0000	0.9999	PRIBOR1W
				1.0000	PRIBOR2W
PRIBOR1M	PRIBOR2M	PRIBO3M	PRIBOR6M	PRIBOR9M	
0.8514	0.8546	**0.8575**	0.8478	0.8430	The deposit rate in the Bank
0.9785	0.9763	0.9752	0.9754	0.9750	2W repo rate
0.9827	0.9812	0.9808	0.9794	0.9785	PRIBOR1D
0.9926	0.9914	0.9907	0.9898	0.9891	PRIBOR1W
0.9942	0.9930	0.9924	0.9916	0.9910	PRIBOR2W
1.0000	0.9996	0.9990	0.9985	0.9978	PRIBOR1M
	1.0000	0.9997	0.9990	0.9985	PRIBOR2M
		1.0000	0.9994	0.9989	PRIBOR3M
			1.0000	0.9997	PRIBOR6M
				1.0000	PRIBOR9M
PRIBOR1Y	CZKSW1Y	CZKSW2Y	CZKSW5Y	CZKSW10Y	
0.8393	0.7723	0.6943	0.6335	0.6305	The deposit rate in the Bank
0.9746	0.9867	0.9565	0.8734	0.8505	2W repo rate
0.9779	0.9834	0.9508	0.8729	0.8521	PRIBOR1D
0.9885	0.9853	0.9456	0.8632	0.8420	PRIBOR1W
0.9904	0.9854	0.9449	0.8628	0.8417	PRIBOR2W
0.9971	0.9750	0.9221	0.8353	0.8143	PRIBOR1M
0.9980	0.9749	0.9221	0.8375	0.8168	PRIBOR2M
0.9985	0.9748	0.9225	0.8395	0.8189	PRIBOR3M
0.9992	0.9758	0.9242	0.8389	0.8168	PRIBOR6M
0.9998	0.9769	0.9273	0.8453	0.8235	PRIBOR9M
1.0000	0.9778	0.9297	0.8503	0.8290	PRIBOR1Y
	1.0000	0.9824	0.9195	0.8983	CZKSW1Y
		1.0000	0.9699	0.9522	CZKSW2Y
			1.0000	0.9964	CZKSW5Y
				1.0000	CZKSW10Y
			CZKSW15Y	CZKSW20Y	
			0.6175	0.6073	The deposit rate in the Bank
			0.8221	0.8118	2W repo rate
			0.8257	0.8158	PRIBOR1D
			0.8141	0.8039	PRIBOR1W

0.8136	0.8034	PRIBOR2W
0.7846	0.7742	PRIBOR1M
0.7874	0.7771	PRIBOR2M
0.7897	0.7795	PRIBOR3M
0.7868	0.7763	PRIBOR6M
0.7936	0.7834	PRIBOR9M
0.7993	0.7894	PRIBOR1Y
0.8723	0.8626	CZKSW1Y
0.9328	0.9249	CZKSW2Y
0.9898	0.9865	CZKSW5Y
0.9978	0.9960	CZKSW10Y
1.0000	0.9992	CZKSW15Y
	1.0000	CZKSW20Y

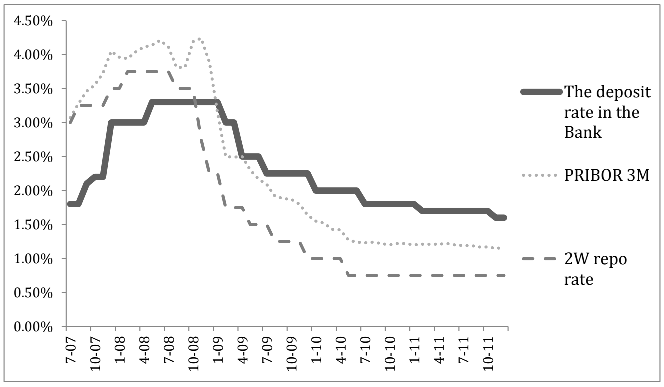
Source: The Bank, www.cnb.cz, author's own calculations. Correlation coefficients, using the observations 2007:07 - 2011:12 with 5% critical value (two-tailed) = 0.2681 for n = 54.

Table 8.2: Correlation between ING deposit rate, the 2W repo rate and selected short-term market rates for the monthly values from 1 January 2002 to 31 December 2012

ING Konto	2W repo rate	PRIBOR 1D	PRIBOR 1W	PRIBOR2W	
1.0000	**0.6558**	0.6872	0.7103	0.7159	ING Konto
	1.0000	0.9920	0.9932	0.9925	2W repo rate
		1.0000	0.9969	0.9956	PRIBOR1D
			1.0000	0.9998	PRIBOR1W
				1.0000	PRIBOR2W
PRIBOR1M	PRIBOR2M	PRBOR3M	PRIBOR6M	PRIBOR9M	
0.7505	0.7706	0.7883	0.8093	**0.8121**	ING Konto
0.9792	0.9711	0.9609	0.9388	0.9255	2W repo rate
0.9816	0.9725	0.9616	0.9367	0.9212	PRIBOR1D
0.9923	0.9857	0.9769	0.9562	0.9427	PRIBOR1W
0.9941	0.9881	0.9799	0.9602	0.9472	PRIBOR2W
1.0000	0.9983	0.9937	0.9795	0.9686	PRIBOR1M
	1.0000	0.9984	0.9887	0.9800	PRIBOR2M
		1.0000	0.9949	0.9885	PRIBOR3M
			1.0000	0.9983	PRIBOR6M
				1.0000	PRIBOR9M
				PRIBOR1Y	
				0.8109	ING Konto
				0.9144	2W repo rate
				0.9086	PRIBOR1D
				0.9313	PRIBOR1W
				0.9360	PRIBOR2W
				0.9587	PRIBOR1M
				0.9716	PRIBOR2M
				0.9816	PRIBOR3M
				0.9948	PRIBOR6M
				0.9989	PRIBOR9M
				1.0000	PRIBOR1Y

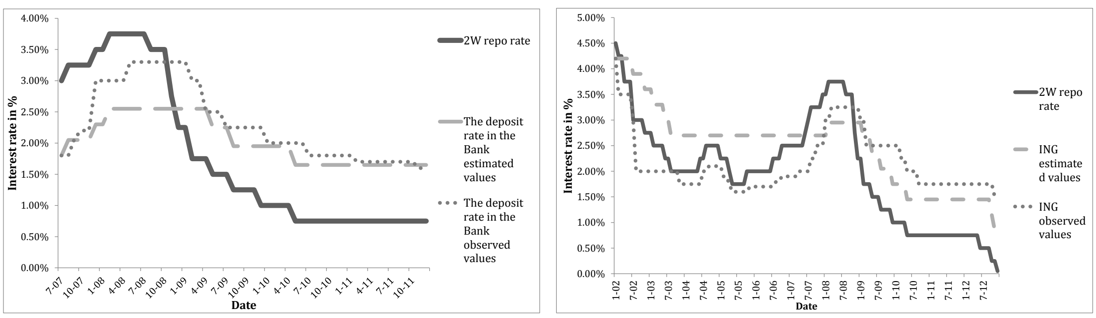
Source: ING, www.cnb.cz, author's own calculations. Correlation coefficients, using the observations 2002:01 - 2012:12 with 5% critical value (two-tailed) = 0.1710 for n = 132.

Figure 8.1: The plot of the deposit rate in the Bank, the 2W repo rate and PRIBOR3M monthly values from 31 June 2007 to 31 December 2011



Source: Author based on ARAD time series database and the Bank

Figure 8.2: The fit of the estimated deposit rate in the Bank to the observed deposit rate in the Bank and the fit of the estimated ING deposit rate to the observed ING deposit rate



Source: Author

8.2 Quarterly and Annual Reports in Selected Banks

8.2.1 Air Bank

Table 8.3: Important numbers from Air Bank's reports

CZK million	12/2011	3/2012	6/2012	9/2012	12/2012
Loans (in retail)	0	0	4,698	6,310	11,135
Deposits in retail	2,234	10,592	18,897	25,052	30,696
of which savings accounts	**2,207**	**NA**	**NA**	**NA**	**30,238**
Net interest income	2	-16	-9	25	116
Net fee income	-8	-1	-4	-7	-41
After tax profit	-282	-130	-284	-398	-323

Source: Author and www.airbank.cz. NA means that data is not available.

8.2.2 Equa bank

Table 8.4: Important numbers from Equa bank's reports

CZK million	12/2010	12/2011	3/2012	6/2012	9/2012	12/2012
Receivables (retail)	2,082	2,847	2,690	3,093	3,855	5,610
Deposits in retail	647	4,475	5,471	5,387	5,688	7,492 *(7,502)
of which available on demand	**NA**	**1,716**	**NA**	**NA**	**NA**	***(5,491)**
Net interest income	47	50	16	30	51	89.5
Net fee income	3	6	-1	0	-3	-7 *(-0.9)
After tax profit	-99	-359	-117	-191	-294	-446 *(-444)

Source: Author based on www.equa.cz. By 3/2013, Equa Bank reports CZK 9,402 million of deposits in retail. *(...) is the number from *Annual report 2012*, whereas the majority of numbers from the table is from *Informace o bance k 31.12.2012* or *Annual report 2011*. The differences are driven by more detailed selection in *Informace o bance k 31.12.2012.*

8.3 Interest Income from the Replicating Portfolio

- **Overnight investment interest income:** The O/N rate is derived from the market rate as $m_t/360$. O/N investment rolls over, i.e. one day increments into volumes are used in the calculation of the new interest income as we assume that a bank after each day reinvests volatile volumes from the previous day + O/N interest income. The total monthly interest income from O/N is:[38] $\mathrm{ONII_{i,t}} = \left(w_i * \mathrm{V_{t-1,i}} * \frac{\mathrm{m_{t-1}}}{360}\right)^{30}$, where i = *The traditional bank, the low-cost bank, the third type bank*, t=(1,…,T). $\mathrm{ONII_{i,t}}$ is the monthly interest income from the O/N investment in each bank, $V_{t-1,i}$ are savings accounts' volumes at the beginning of the month and $m_{t-1}/360$ is the O/N rate.

- **3M investment interest income:** 3M yield is derived from the yield curve at time t for the market rate m_t for each t as defined in the equation (4.3). 3M investment rolls over at maturity, i.e. interest income + balance returned are reinvested as new volumes. The total monthly interest income from 3M positions (those that mature in t) in each type of bank is: $\mathrm{3MII_{i,t}} = w_i *$

[38] We employ 30/360 discounting.

$\mathrm{V}_{\mathrm{t-3,i}} * \frac{3\mathrm{M}_{\mathrm{t-3}}}{4}$, where i=*The traditional bank*, *the low-cost bank*, *the third type bank*, t=(1,…,T). $3MII_{i,t}$ is the monthly interest income from 3M investment that matures in the given month in each bank, $V_{t-3,i}$ is the savings accounts balance three months ago and $3M_{t-3}$ is the 3M annualized yield derived from the equation (4.3).

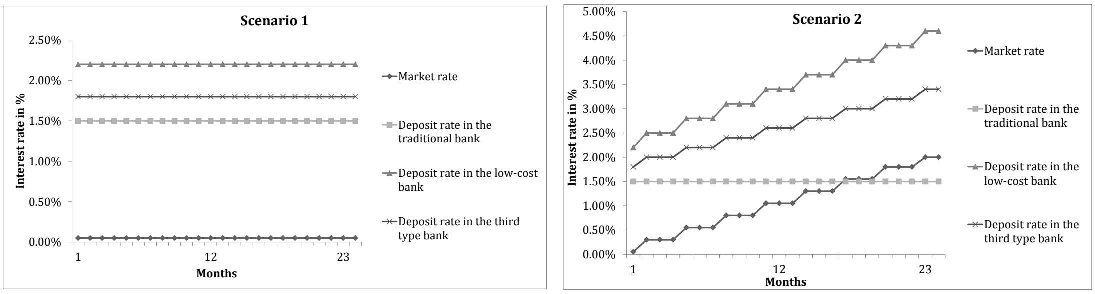
- **6M and 1Y investment interest income:** The interest income for 6M and 1Y is calculated similarly as 3M investment interest income.
- **10Y and 5Y investment interest income:** The calculation of the interest income from any maturity higher than one year is straightforward as the equation (4.3) provides annualized yields. Therefore, 10(5)Y monthly ($10(5)YII_{i,t}$) investment yield is as follows: $10(5)YII_{i,t} = w_i V_{i,t-12}$.
- **Interest income from loans:** We obtain monthly payments from loans as coupons from annuity using the equation from Mejstřík, et al. (2008): $\text{consumer loan} = \mathrm{C_i}\left[\frac{1}{\mathrm{r_i}} - \frac{1}{\mathrm{r_i}(1+\mathrm{r_i})^{\mathrm{T}}}\right]$, where C_i is the monthly payment in each type of a bank and $r_{i,t}$ consumer loans' interest rate at time t[39] in each type of a bank. We then define the interest income of a bank in each month as: $CLII_{i,t} \frac{\mathrm{T*C_i} - \text{consumer loan}}{\mathrm{T}} * \mathrm{CL_{t-1}} * d_i$, where i =*The traditional bank*, *the low-cost bank*, *the third type bank* and CL_{t-1} is the number of consumer loans provided at time t-1 and d_i are defaults. Monthly payments (with the interest income included) are used to generate new loans whereas the interest income only is used to calculate the margin from consumer loans position.
- **Interest income from mortgages:** The interest income from mortgages is obtained in the similar fashion as the interest income from loans, i.e.: $\text{mortgage} = \mathrm{P_i}\left[\frac{1}{\mathrm{r_i}} - \frac{1}{\mathrm{r_i}(1+\mathrm{r_i})^{\mathrm{T}}}\right]$, where P_i is the monthly payment from mortgages in each type of a bank and r_i is 5Y fixed interest rate on mortgages in each type of a bank. We then define the interest income of a bank in each month as $\frac{\mathrm{T*P_i} - \text{mortgage}}{\mathrm{T}} * \mathrm{M_{t-1}} * d_i$, where i=*The traditional bank*, *the low-cost bank*, *the third type bank*, t=(1,…,T), M_{t-1} is the number of mortgages

[39] Recall that consumer loans' interest rates grow at the growth of the market rate.

provided at time t-1. Monthly payments (with the interest income included) are used to generate new mortgages whereas the interest income only is used to calculate the margin from consumer loans position.

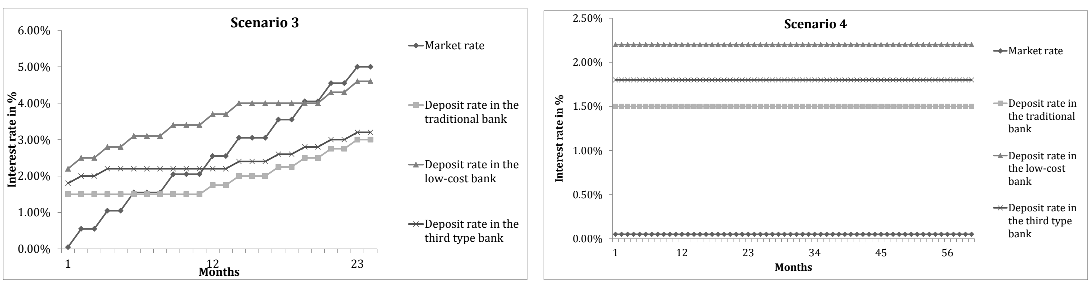
8.4 Market and Deposit Rate Scenarios

Figure 8.3: The dynamics of the market rate and deposit rates for Scenarios 1 and 2



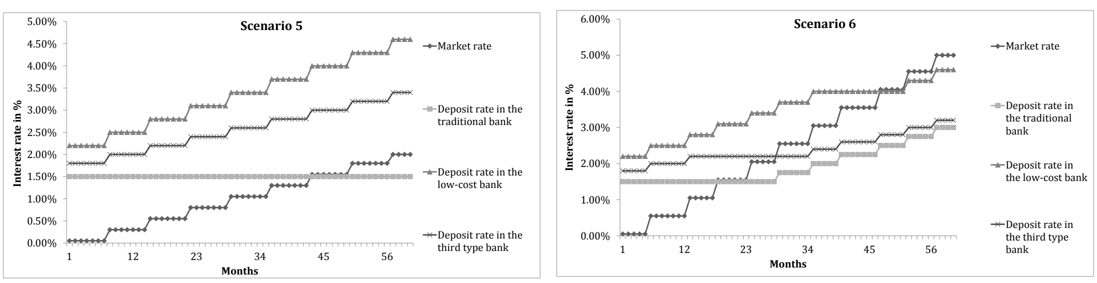
Source: Author

Figure 8.4: The dynamics of the market rate and deposit rates for Scenarios 3 and 4



Source: Author

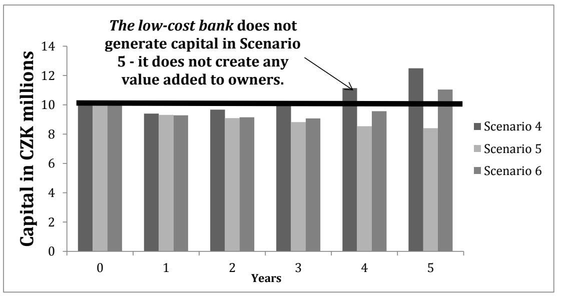
Figure 8.5: The dynamics of the market rate and deposit rates for Scenarios 5 and 6

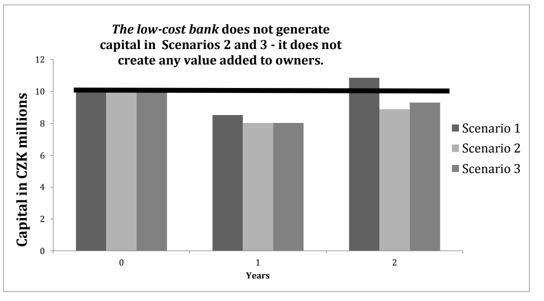


Source: Author

8.5 The Impact on Capital

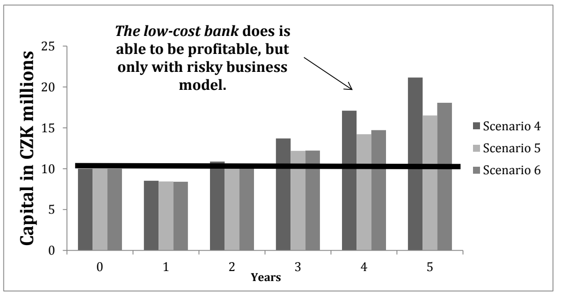
Figure 8.6: The impact on capital for a non-aggressive strategy and Scenarios 4-6 and for an aggressive strategy and Scenarios 1-3





Source: Author

Figure 8.7: The impact on capital for an aggressive strategy and Scenarios 4-6



Source: Author

8.6 Systemic Risk

8.6.1 The Reinvestment of the Median Bank

Table 8.5: The reinvestment of *the median bank*

Deposit rate initial value: 1.83%
Difference for adjustment upwards: 75 bps
Adjustment upwards: 25 bps
Replicating portfolio:
10% of deposits is invested into O/N rate.
10% of deposits is invested into 3M.
40% of deposits is invested into 10Y.
40% of deposits is distributed as loans and mortgages to clients:

4. 13.3% of deposits is invested into 1Y fixed rate consumer loans for CZK 30,000 with r = 18.33%.
5. 13.3% of deposits is invested into 5Y fixed rate consumer loans for CZK 100,000 with consumer loans' interest rate of r =13.33%.
6. 13.3% of deposits is invested into 20Y fixed rate (fixing for 5 years) mortgages for CZK 1,000,000 with 4% rate.

Source: Author